HYDROLOGIC SURVEY and ANALYSIS

Water and Related Land Resources

RED ROCK CANYON

PATAGONIA RANGER DISTRICT

CORONADO NATIONAL FOREST

ARIZONA

U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE SOUTHWESTERN REGION

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FOR

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By

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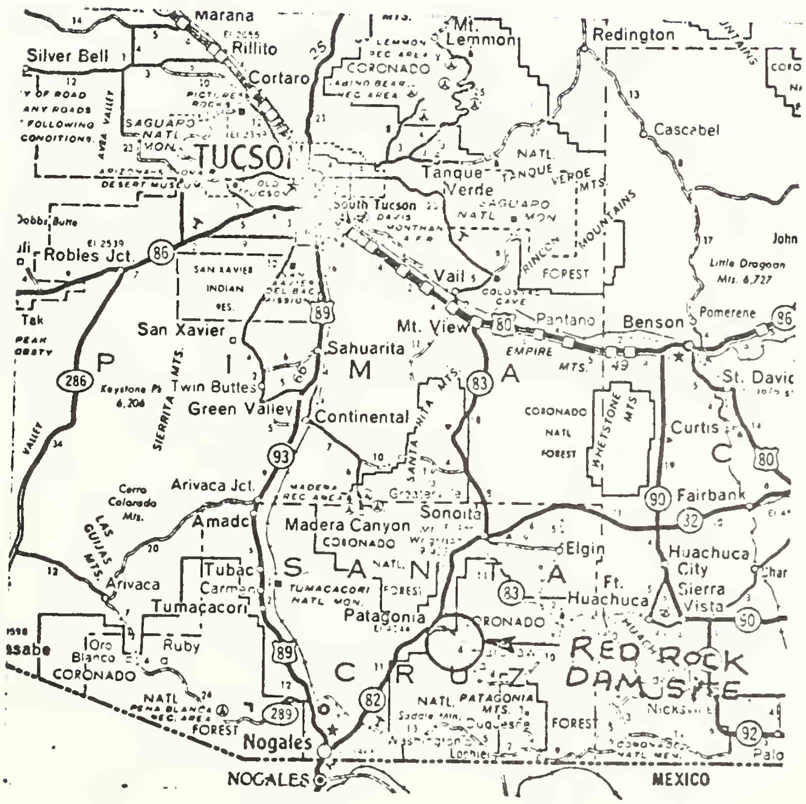
VICINITY MAP

Showing location of Red Rock Reservoir in relation to Tucson, Nogales, and Patagonia, Arizona.



I. ABSTRACT

The Arizona Game and Fish Department has under consideration a proposed dam to be constructed at Dam Site "A" in Red Rock Canyon.

The Forest Service conducted an intensive hydrologic survey in this watershed investigating the hydrology, geology, and soils.

Location

The Red Rock Canyon Watershed is located in Central Santa Cruz County, Arizona. By road, it is approximately 55 miles southeast of Tucson, 20 miles northeast of Nogales, and 4 miles east of Patagonia. The Watershed has an approximate area of 28 square miles and comprises portions of townships 21 and 22 south, ranges 16 and 17 east, Gila and Salt River Meridian.

For the purpose of this report, the term Redrock Canyon Watershed will be used to designate only that portion of the Redrock Canyon drainage upstream from the proposed Dam Site "A".

SUMMARY

Drainage Analysis and Hydrologic Response Units

1. Red Rock was broken into 8 sub-drainages for the purpose of routing and collecting water. Twenty-six hydrologic response units were delineated on the 8 sub-drainages to describe the soil, vegetation and hydrometeorlogical data. Water balances were computed on each HRU using 32 years of record to determine the volume of water in acre-feet which would be produced from each HRU.

2. Watershed Simulation Model

Analyzing 32 years of hydrometeorlogical data, and monthly streamflow from the USGS gage the Red Rock Canyon watershed will yield an average of 0.50 inches of water per year. This is 747 ac.ft. of water to dam site "A".

The watershed model is essentially a mathematical reproduction of the hydrologic processes within the hydrologic cycle. The inputs into this model are:

a. Precipitation - U.S. Weather Bureau records were analyzed from 1935 to 1967, and monthly precipitation extracted.

b. Temperature - Temperature data from 1935 to 1967 for Canelo, San Rafael, and Nogales Stations indicated a lapse rate of 3.19° per 1,000 foot change in elevation. Because of its close proximity to Red Rock the Canelo Station was used as a base. Elevation adjustments in temperature for each hydrologic response units were determined.

c. Potential Evapotranspiration (PE) - The Thornthwaite equation was used to predict monthly PE from each HRU. Potential Evapotranspiration can be defined as the maximum possible evapotranspiration (ET) from an area with unlimited available water and a cover at 100 percent density. Because of limiting water supply during portions of the year, actual ET was computed using a soil moisture depletion function. Also, because slope and aspect affects the amount of energy available for ET, a slope-aspect correction factor was applied to computed PE.

d. Lake Evaporation - The Lake Hefner Lake Evaporation Equation was used to predict Lake evaporation from the simulated Red Rock Reservoir. Because there was not a climatic station at the proposed Lake site, the parameters in the equation were extrapolated from surrounding weather stations through development of a series of prediction equations.

e. Soil Moisture Depletion - Soil moisture depletion function was used to describe the soil moisture release characteristics in response to potential evaporation. The depletion constant input is dependent on the physical characteristics of the soil and the amount of soil moisture in storage.

f. Ground Water Depletion on Base Flow - A ground water depletion function was used to describe the characteristics of the watershed with a certain amount of water in storage. Over 300 daily recession flows in a four year period at the Sonoita Creek gage were analyzed and a prediction equation was developed RELATING monthly precipitation to a mean monthly recession constant.

g. Interception - Precipitation falling on the watershed was reduced by interception for determination of net precipitation that enters the soil and groundwater reservoirs. The parameters in the interception equation were varied by season to allow for variations in seasonal differences in storm intensity and duration and nature of the plant cover.

Using the watershed model and the 32 years of hydrometeorological inputs monthly runoff from the Red Rock Canyon watershed was simulated for calendar years 1936 to 1967. Using a routing and combining program and a reservoir filling program, the simulated runoff was used to determine average reservoir filling time, volume of spill per year and volume of water in storage.

Sediment Yield

Total sediment yield from Red Rock Canyon above damsite "A" is 7.24 Ac.ft. per year. 5.6 percent of the sediment comes from sheet erosion. From the sediment yield calculations, a dam of 125 surface acres at site "A" will lose 20 percent of its storage capacity over a 100 year period.

Total sediment yield from the potentially treatable areas in the Patagonia and Santa Rita Mountains is 0.97 Ac.ft. per year. 25 percent of the total sediment yield comes from sheet erosion. Conversion to a grass cover will result in a net increase of 0.05 Ac.ft. year. Maintenance of existing roads would result in a net decrease from the whole area of 0.13 Ac.ft. per year.

In-Channel Depletions

Depletions from the deep aluvial channels was accounted for in the simulation study. The 96 acres of alluvial bottoms within the Red Rock

watershed were delineated as two HRU 3A4, and 8B4. Subwatersheds 1 through 3 were routed into HRU 3A4 and subwatersheds 4 through 6 plus HRU 3A4 and 8B1 were routed into HRU 8B4. Losses from riparian evapotranspiration were computed for the alluvial channel HRU's.

From seismic tests, the average depth of the streambed alluvium and terrace deposits was found to be 20 feet. Depth to the water table average 6 feet, with an average porosity of alluvium of 30 percent. An average depth to water of 12 feet was used in the simulation study. When the depth to water was less than 12 feet, the excess water was routed out of the alluvial channels. Total water storage at the 12 foot level was 230 Ac.ft.

Design Storm - Flood

A 3.5 inch - 1 hour storm can be expected on some part of this watershed every 10 years or less. A peak discharge of 1500 cfs. per square mile probably occurs on some small part of the principal watershed several times in 10 years. Runoff from these small areas could produce 137 ac.ft. per square mile. This would produce 1058 ac.ft. of water to damsite "A".

For dam design purposes a 4.5 inch 6 hour storm is the minimum acceptable storm for spillway determination and freeboard. This storm would produce 2166 ac.ft. to damsite "A".

Water Quality for Sonoita Creek

Chemical analysis of water in Sonoita Creek shows that the water is of calcium bicarbonate, sulphate type, hard and of moderate to high dissolved solids content. Hardness is an undesirable characteristic of water used for domestic purposes. The water of the basin is very hard, exceeding 144 ppm, and reaches as high as 800 ppm.

Analysis of Flow - Sonita Creek USGS Gage

An analysis of a seismic investigation conducted at the USGS gage on Sonoita Creek near Circle Ranch showed the gage to be 11% in error for median annual flow. This means that 518 ac. ft. of water per year by-pass the gage in the unconsolidated alluvium beneath the gage.

As of February 9, 1969, 3,294 ac. ft. have been stored in Lake Patagonia. Outflow has been 1,096 ac. ft. to satisfy downstream water rights.

From February 9, 1969, it is predicted that 147 days will be required to bring the storage in Lake Patagonia to spillway level.

Using the figures of average daily flow passing the USGS gage for 137 days of reservoir filling gives 544 ac. ft. The 21 sq. mi. area below the gage contributed 367 ac. ft. Flow underneath the gage amounts to 194 ac. ft. for the 137 days of reservoir filling.

A total balance shows that our figures are only off 17 ac. ft. for the 137 days, which is insignificant.

Surface Water Analysis

Gaged runoff from Sonoita Creek watershed averages 0.51 inches or 5,723 ac. ft. per year. Because of the 11% error in the USGS gage from underflow this figure is probably closer to 6,200 ac. ft. per year.

From the watershed simulation model using 32 years of record above damsite "A" in Red Rock Canyon the mean annual runoff computes to be 0.50 inches or 747 ac. ft. per year.

On the average a dam constructed at site "A" with a storage of 125 surface acres will require $8\frac{1}{2}$ years to fill. The minimum time is one month, and the maximum time is 19 years. The above figures are based on yearly inflow to the lake from the watershed without using any flood runoff. Flood runoff can be expected once every 10 years or less with a minimum inflow of 1,058 ac. ft. of water.

Once the dam is filled, the surface area of the lake will average 105 acres in size.

The average volume of spill per year is 365 ac. ft. per year.

The average evaporation loss will be 285 ac. ft. per year.

The leakage from the dam, assuming a tight seal, would be a minimum of 74 ac. ft. per year. This is 2% and could range as high as 5%.

The results of the simulation study show that during the 32 year period, 34 months, or 9 percent of the time, runoff from Red Rock Canyon was less than 6.13 ac. ft. per month. Because of the minimum leakage from the site, runoff will be greater during low flow from Red Rock Canyon with the reservoir than without it.

Geology - The Red Rock Canyon Watershed is a contributor to the Sonoita Creek Groundwater Basin; both being contained within the basin and range geomorphic province. Dominant rock units within the watershed are alluvium and flows of andesite and rhyolite. The dominant structural trend is northwest-southeast; secondary structural trends are east-west and northeast-southwest. Surface flow occurs in both the watershed and Sonoita Creek when the near surface presence of igneous rock of relatively low permeability forces the water table to intersect the ground surface. Within the watershed surface flow ceases when the volume of high permeability alluvium exceeds the volume of the surface flow thereby allowing the water table to sink below the ground surface. Indications are that the groundwater of Red Rock Canyon Watershed is all going to the Sonoita Creek Groundwater Basin. However, extensive fracturing of the igneous rocks allows the near surface flow to deviate considerably from the stream channel flow.

Soils - Soils of the Red Rock Watershed are generally shallow and stony on steep slopes of the outer perimeter area and rolling to steep surfaces of the interior basin. Heavy textured soils of variable depth occupy approximately 18 percent of the lower slopes and a section of the upper reaches of Red Rock Creek.

Revegetation within the watershed would be ineffective for increasing water yields of the soil for the following reasons:

1. Stand densities of deep rooted trees and shrubs are too low for effective water depletion of the subsoil below depletion levels of grassland.

2. Levels of available water within the shallow profiles over 80 percent of the area are generally low. This moisture would be used primarily for evapotranspiration during dry periods.

3. Heavy textured soils within the remainder of the watershed are low in water yield and permeability and support thin stands at deep-rooted vegetation with grass.

Revegetation within treatable areas on the Santa Rita and Patagonia Watersheds which contain dense stands of deep-rooted vegetation will effectively increase water yields to Sonoita Creek. Under the conditions of high erosion potential on each unit, this treatment will require careful management.

Economic Summary

Evaluation Objectives

The purpose of an economic analysis and evaluation is to give the Natural Resources Manager meaningful socio-economic information regarding various management alternatives. The management of natural resources has become extremely technical and complex. Good old sweat and blood management, custodial approaches to management, and cursory evaluation of alternative management objectives are not adequate to meet the natural resources needs of today or the expectations of people about to emerge into the 21st century. Present and future resource management calls for the best planning and program solving techniques available.

This indicates the need to use systems that evaluate the physical, social, and economic aspects of each alternative and if operating properly, help force new alternatives to the surface. Several indicators (multiple criteria)1/ are needed to do this. These indicators (criteria) may include benefit-cost ratios, with project versus without the project comparisons, physical output in numbers, employment and target group indicators, income indicators such as dollars direct benefit or secondary benefits, dollars net present worth, internal rate of return for a given alternative, benefits foregone (opportunity costs) and others. They are used to compare and weigh the various alternatives that could be used in allocating limited resources to provide for the well-being of the people. These systems cannot make management decisions, but they can give the resource manager a key part of a sound and supportable base from which to make decisions.

Evaluation Results

An economic evaluation was first made to detemine what present and future expected net benefits would be from the Red Rock Watershed if the Red Rock Dam complex were not installed--this is a without the project situation. The analysis showed that the expected net present worth of benefits discounted at 4 and 5/8% over a 40 year time period would be $933,860 or an annual equivalent value of about $49,460 per year. The outputs or commodities produced and their values that make up these figures are shown in tables 1, 2, and 3.

1/ Refer to economic section in appendix that describes and defines various economic terms - as needed.

TABLE 1. Without the Project - Present Worth of Benefits and Costs expected to Accrue from the Red Rock Watershed over the Forty Year Time Period 1/

Commodity	$Benefit $P.W._{40}$	$Cost $P.W._{40}$	$Net $P.W._{40}$
Hunting	80,247	0	80,247
Forage	357,770	39,213	318,557
Wood Fibre	21,433	5,425	16,008
Rock Hounds (Collectors)	6,399	0	6,399
Natural Beauty	-	-	-
Flood Damage	0	397	-
Roads	0	3,615	-
Fire	0	1,681	-
Mining	na	na	na
Sediment	0	4,880	-
	$465,849	$55,211	

Net $P.W._{40}$ = $410,638

Downstream

Other uses	$216,085
Lake Patagonia	$307,140
Net $P.W._{40}$	= 523,225

Net $P.W._{40}$ = $933,860

1/ Discounted to present values (1969) at a rate of 4-5/8%

TABLE 2. Without the Project - Annual Net Primary and Secondary Value of Commodities Produced from Red Rock Watershed and It's Contribution to Downstream Benefits

Commodity	Net Primary Benefit	Multiplier 1/	Net Secondary Benefit
Hunting	$ 4,438/YR	1.3	5,769
Forage	$ 15,177/YR	1.3	19,730
Wood Fibre	$ 881/YR	1.2	1,057
Rock Hounds (Collectors)	$ 354/YR	1.3	460
Mining	$ N.A.	1.6	N.A.
Water			
Ranching (Misc.)	$ 22/YR	1.1	24
Irrigation	$ 506/YR	1.2	607
Municipal	$ 3,050/YR	1.3	3,965
Ornithology-(Bird Sanctuary)	$ 6,564/YR	1.3	8,533
Dude Ranch	$ 1,810/YR	1.2	2,172
Lake Patagonia	$ 16,990/YR	1.3	22,087
	$ 49,792/YR		64,404/YR
-Nonseparable Costs	-328/YR		-328/YR
Total/Yr	$ 49,464/YR		$ 64,076/YR

1/ (19) Arizona Review, February 1967.

Table 3 Without the Project-National Economic Sector Values - Primary and Secondary Value of Commodities Produced from Red Rock Watershed

National Economic Sector 1/	Net Primary Benefits-$/YR	Secondary Benefits-$/YR
Agriculture		
Crops	$ 528	$ 631
Livestock and Livestock-Products	$15,177	$19,730
Manufacturing		
Non Durable Goods	$ 881	$ 1,057
Selected Services	$33,206	$42,986
Mining	NA	NA
Nonseparable Costs	$ -328	$ -328
Total Annual Net Benefits	$49,464/YR	$64,076/YR

1/ Based on City and County Data Book, Dept. Commerce, 1967.

The second phase of the evaluation involved the proposed Red Rock Dam complex and nine alternative ways of accomplishing it. In both with and without the dam complex evaluation, the benefits represent additional money added to the local and immediate area of Patagonia, Arizona. Benefits or portions of benefits that were likely to accrue outside the area were not included.

The dam complex represents a with the project situation. All nine management alternatives were found to be economically feasible if each alternative was developed to at least a certain minimum scale or size. One alternative was recommended over the others as being the most optimum to meet the objectives. Its benefits exceeded the benefits of not having a Red Rock Dam complex (a with versus without comparison) by a range of from $41,000 net present worth value to about $7,500,000 net present worth over a 40 year period; and depended on the scale or size of development chosen. The optimum development occurred at approximately 163 acres of reservoirside recreation. However, budgeting would probably become a limiting factor before this scale could be reached.2/

The characteristics of the area and its geographic location interact in such a way that the proposed Red Rock Dam complex must have relatively well developed and complete recreation facilities before the benefits that would make the project feasible can occur. This requires that the project must include the development of picnicking and camping facilities. If not included, the other benefits that accrue over time will not cover all the costs. And in that case, the future net benefits from the area with the project would be less than those that would occur without the project. If so, it should not be undertaken from a socio-economic point of view.

2/ The benefits described and tables 4 and 5 that list the values for various scales of development are not just for picnicking and camping but include: fishing, hunting, grazing or forage production, wood fibre, natural beauty, and rock (hounds) collecting, as onsite benefits. Offsite benefits include: water for ranching, irrigation, municipal-industrial, bird sanctuary (ornithology), dude ranching, and Lake Patogonia. Costs are also comphrehensive and cover both onsite and offsite situations.

Recommended Alternative

The project alternative that has been recommended to the Resource Manager is the one that combines Harshaw Creek access road and two standard boat ramps along with camping and picnicking development. This is based on the socio-economic evaluation of the nine multiple use management alternatives as developed with the Patagonia Ranger District and Coronado National Forest.

As explained earlier, the net present worth of benefits depend on the scale of development chosen. Benefits, costs and other evaluation criteria for the alternative recommended are shown in Table 4. These cover the range scale of development found to be socio-economically feasible. The various scales of picnicking and camping development that are required to obtain these benefits are shown in Table 5.

Included in the proposed Red Rock Dam complex is the provision for vegetative type conversion to augment downstream water needs. This additional water would add to downstream flows expected from dam spilling and reservoir leakage. The optimum type conversion treatment combination to accomplish this was derived by using linear programming.

The results of the L-P analysis, the volume of additional water produced, the net benefits and the costs involved are shown in Tables 6 and 7. Note that if the net benefits per acre treated or the water yield per acre treated is examined, they are found to be quite low. This indicates the need to seek other possible methods of producing additional water. This is primarily due to the very limited increased water yield potential of the hydrologic response units suitable for type conversion within the project area.

Table 4. Economic Evaluation Data on the Recommended Management Alternative for The Red Rock Dam Complex - A With vs. Without the Project Comparison 1/

Scale of Lakeside Recreation Development Required-Acres	Net Present Worth 2/ of Benefits - $	Annual Equivalent 3/ Net Benefits - $YR	Benefit-Cost Ratio	Internal 4/ Rate of Return -%	Initial 5/ Cost - $	Total 6/ Cost-$
10	41,650	2,350	1.1 : 1.0	2.6	112,850	125,710
15	287,500	16,200	1.3 : 1.0	6.5	130,810	147,850
20	604,150	34,050	1.6 : 1.0	8.0	148,770	169,990
25	845,800	47,670	1.9 : 1.0	8.9	166,730	192,130
30	958,300	54,010	2.0 : 1.0	9.8	184,690	214,270
40	1,604,150	90,410	2.7 : 1.0	11.7	220,620	258,550
50	2,270,800	127,980	3.4 : 1.0	13.4	256,540	302,840
60	2,916,650	164,380	4.1 : 1.0	14.9	292,460	347,120
80	4,145,800	233,660	5.4 : 1.0	17.6	364,310	435,680
100	5,333,300	300,584	6.7 : 1.0	15.5	436,150	524,240

1/ Recommended alternative utilizes Harshaw Creek access road, two standard boat ramps and picnicking and camping at scales shown. Benefits include onsite — hunting, grazing, wood fibre, natural beauty etc., and offsite water

2/ These figures represent the present worth of benefits accruing over the 40 year period minus the present worth of costs over the same period for the total system. This is equivalent to a with and without the project comparison since the net benefits accruing without the project were subtracted out as an opportunity cost. They are less than costs in the other columns because they are net values discounted to the present time.

3/ Undiscounted net benefits that would occur as an average each year over the 40 year period.

4/ That rate of interest where future costs and benefits discounted to the present become equal.

5/ The initial cost of the Harshaw Creek access road($461,570), the dam installation and fisheries stocking are not included in these figures but they and all others were included in calculating the net benefits columns.

6/ Includes all installation, operation, and maintenance costs except for those of the access road, dam, and fisheries management and law enforcement.

Table 5. Acres of Picnicking and Camping Development Required to Obtain Net Present Worth Benefits and Benefit-Cost Ratios shown in Preceding Table 4.

Total Acres	Acres of Picnicking	Acres of Camping	Net Present Worth 1/ of Benefits - $	Benefit-Cost Ratio	Minimum Annual Visitor Days of Recreation Demand Served
10	4.5	5.5	41,650	1.1 : 1.0	12,000
15	6.7	8.3	287,500	1.3 : 1.0	17,500
20	8.0	12.0	604.150	1.6 : 1.0	23,500
25	11.2	13.8	845,800	1.9 : 1.0	29,000
30	13.5	16.5	958,300	2.0 : 1.0	35,000
40	18.0	22.0	1,604,150	2.7 : 1.0	47,000
50	22.5	27.5	2,270,800	3.4 : 1.0	58,500
60	27.0	33.0	2,916,650	4.1 : 1.0	70,500
80	36.0	44.0	4,145,800	5.4 : 1.0	89.500
100	45.0	55.0	5,333,300	6.7 : 1.0	90,500

1/ These figures represent the present worth of benefits accruing over the 40 year period minus the present worth of costs over the same period for the total system. This is equivalent to a with and without the project comparison since the net benefits accruing without the project were subtracted out as an opportunity cost. They are less than costs in the other columns because they are discounted to the present time.

Augmenting Downstream Water Needs

To augment downstream water needs vegetative type conversion was analyzed. This involved using linear programming coupled with economic evaluation to develop an optimum solution for vegetative type conversion. It was found that on an average annual basis, about 87.5 acre feet of new water could be developed and delivered to Patagonia. The net present worth of benefits from this water over the 40 year period would be about $28,000. About 20% of these benefits would come from reduced fire suppression and fire impact costs, the remainder are from the new water. The new water net benefits are relatively low on the basis of acre feet additional yield per acre of land treated. This is due to the relatively limited additional water potential on the areas suitable for treatment. A search for new alternatives to increase flows in this area appears needed.

Natural seepage from the reservoir and dam spilling could provide an additional $110,000 in benefits. Over the entire 40 year period, the $523,200 of downstream opportunity costs could be reduced by as much as $138,000 from the use of new water, dam spilling and reservoir seepage. This was not taken out of the opportunity cost in the with and without project evaluation. If it were, benefit cost ratios would be more favorable for a given scale of development.

The benefits, costs, and other economic evaluation criteria for vegetative type conversion of brush areas are shown in Table 6 for the various amounts of water yield. The dotted line at 87.5 acre feet indicates that although more water can be produced, none of the additional water would enter Sonoita Creek above Patagonia and the Patagonia-Sonoita Creek Bird Sanctuary.

Table 6 Optimal Solutions on Areas To Treat for Various Yields of New Water Based on the Objective Function of Maximizing Net Present Worth1/

Hydrologic Response Areas2/

New Water -A.F./Yr	Treatment 1 - Spray & Spray (2)	(3)	(4)	(5)	Treatment 2 - Burn & Spray (2)	(3)	(4)	(5)	P.W. Cost-$	P.W. Benefits-$	Net P.W.-$
25		305		200					14,466	22,921	8,454
50		410		200					28,583	45,226	16,643
75		410		390		115			42,955	67,561	24,606
100 3/	153	410		390		137		130	57,458	86,982	29,524
125	457	410		390		137		130	71,614	103,370	32,094
150	762	410		390		137		130	85,769	120,400	34,664
175	1,067	410		390		137		130	99,925	137,200	37,234
200	1,151	410	221	390		137		130	114,300	153,900	39,557
225	1,151	410	489	390		137	37	130	128,900	170,600	41,721
250	1,151	410	489	390	178	137	164	130	144,100	187,300	43,213
266	1,151	410	489	390	372	137	164	130	154,000	198,000	44,076

1/ Small acreages may need to be dropped or rounded off in actual field application.

2/ Hydrologic response areas 3 and 5 are above the Patagonia-Sonoita Creek Bird Sanctuary.

3/ If only area 3 and 5 are treated at this scale then the maximum new water yield for areas above Patagonia has been reached at 87.5 acre feet or 1,066 acres treated.

Table 6A — Economic Evaluation of Additional Benefits from Vegetative Type Conversion to Augment Downstream Water Needs in the Patagonia Area

New Water A.F./YR	Acres Treated	Net Present Worth 1/ of Benefits - $	Annual Equivalent 2/ Net Benefits - $/YR	Internal Rate of Return - %	Initial 3/ Cost - $	Total 4/ Cost - $
25	305	8,460	520		10,610	25,250
50	610	16,640	1025		20,210	49,500
75	915	24,610	1520		30,170	73,400
87.5 5/	1066	28,000	1730	9.2	35,410	75,080
100	1219	29,520	1820		40,270	90,240
125	1524	32,090	1980		52,880	125,360
150	1829	34,660	2140		62,490	146,600
175	2134	37,234	2300		72,080	173,850
200	2439	39,560	2440		82,200	194,400
225	2744	41,720	2570		91,920	218,540
250	3049	43,210	2665		102,340	241,870
266	3243	44,080	2720		109,140	256,710

1/ These figures represent the present worth of benefits accruing over the 40 year period minus the present worth of costs over the same period. They are less than cost figures in other columns because they are net values and are discounted to the present.

2/ Undiscounted net benefits that would occur each year as an average over the 40 year period.

3/ Undiscounted costs over the first 3 years.

4/ All undiscounted installation, operation, and maintenance costs over the 40 year period are included.

5/ Additional water from an area in excess of 1066 acres would enter Sonoita Creek below Patagonia and the Patagonia-Sonoita Creek Bird Sanctuary.

Table 7 Initial Investment Costs of Type Conversion for Various Scales of Water Yield Increase Based on Maximizing Net Present Worth of Benefits

- Total $

New Water 1/ -A.F.	Acres Treated	Initial Costs 2/	New Water Average AF/AC/YR 3/
25	305	10,608	0.082
50	610	20,215	0.082
75	915	30,168	0.082
100	1,219	40,271	
125	1,524	52,883	
150	1,829	62,490	
175	2,134	72,097	
200	2,439	82,205	
225	2,744	91,924	
250	3,049	102,343	
266	3,243	109,139	0.082

1/ Acre feet increments of new water and acres treated are the same under both methods of analysis because yield per acre treated is about the same on the four hydrologic response areas.

2/ These are the undiscounted costs for the initial investment period of 3 years.

3/ The average new or increased water yield of 0.082 AF/AC/YR is equivalent to about 0.98 inches increase per unit of area.

Conclusions

1. The project is feasible if there is development of picnicking and camping facilities.

2. The water yield from Red Rock Canyon is 0.50 inches per year. This is 747 acre feet of water delivered to the mouth of the watershed.

3. Total sediment yield to Dam Site "A" is 7.24 acre feet per year. This will result in a 20% reduction in storage capacity over a 100 year period.

4. U.S.G.S. gage records over 32 years of record are 11% in error.

5. On the average a dam constructed will require $8\frac{1}{2}$ years to fill. A minimum time of one month to fill could be expected. A maximum time of 19 years to fill could be predicted.

6. The average evaporation loss is 285 acre feet per year.

7. A minimum of 74 acre feet per year will be lost to seepage at the proposed reservoir this is 2% of the total volume. A 5% loss due to seepage would not be unreasonable.

8. During the 32 years of record which were analyzed, 34 months, or 9 % of the time, runoff from Red Rock Canyon was less than 6.13 acre feet per month. Because of the minimum leakage of 74 acre feet per year. Runoff from Red Rock would be increased during low flow periods because of the dam.

9. Net benefits from

Fishing, Hunting, Wood Fibre, Natural Beauty, Rock Hounds and Flood Reduction would increase with the project. The slight loss in forage production may be compensated by more intensive management and ongoing spray programs.

10. The benefits that would accrue to the local and immediate area of Patagonia with the dam complex and 25 acres of camping and picnicking development would have a net present worth of about $845,800. This would be about $47,670 annually over a 40 year period. Net benefits would be higher if the scale of development were increased (see table 4).

11. Downstream water needs can be augumented by about 87.5 acre feet annually through type conversion. These benefits have a net present worth of $28,000 over the 40 year period and could raise minimum flows downstream during the low flow period.

12. As the need was pointed out for the Santa Cruz Basin in the Water Resources Council 1968 Report, The Nations Water Resources, this project could help conserve water for beneficial use in the local areas by regulation of flood flows from summer storms.

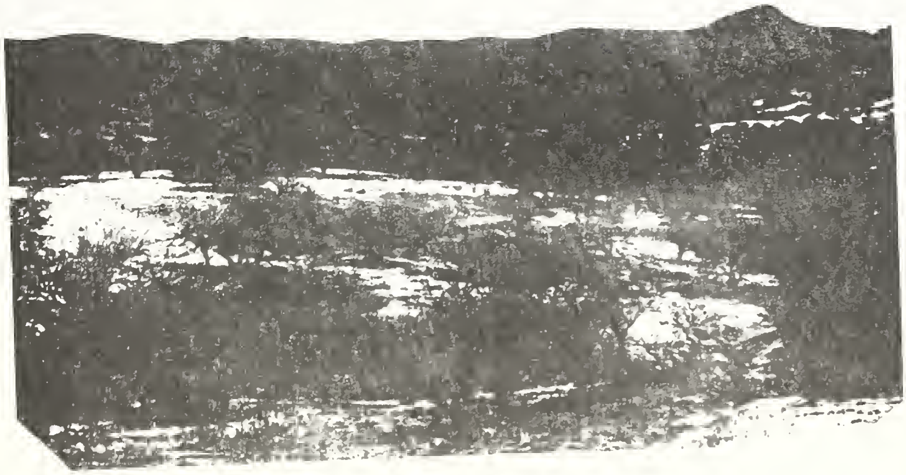
Management Alternatives

Because of the Multiple Use implications in building a reservoir on the Patagonia Ranger District, management alternatives are not included in this hydrologic survey and analysis.

As outlined in the Appendix, a complete hydrologic, soil, geologic and economic analysis was made to help the forest supervisor make logical decisions for the optimum recreation mix regarding this area.

The proposed dam is sound from a hydrologic standpoint, and is economically feasible providing the Multiple Use restraints are considered in allowing construction of a reservoir in an area where frugality of use of water is being practiced by the Forest Service.

General Views of vegetation and topography in Red Rock Canyon Watershed.

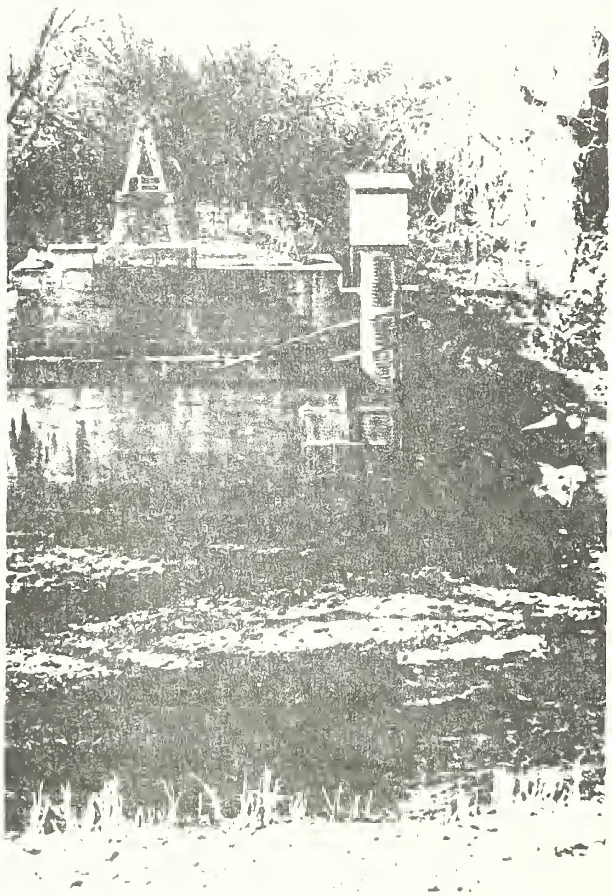


General views of vegetation and topography in Red Rock Canyon Watershed.

Beginning of flow in Sonoita Creek at the Town of Patagonia

Flow in Sonoita Creek 1/4 mile downstream from Patagonia.

Two views of flow in Sonoita Creek through Bird Sanctuary.



Flow at U.S.G.S. gaging station below Bird Sanctuary and above Lake Patagonia.

HYDROLOGIC SURVEY and ANALYSIS

Water and Related Land Resources

RED ROCK CANYON

PATAGONIA RANGER DISTRICT
CORONADO NATIONAL FOREST
ARIZONA

U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE SOUTHWESTERN REGION

APPENDIX

APPENDIX IV

ECONOMICS

Section A. Economic Characteristics of the Red Rock Watershed and its Commodity Values

Section B. Economic Evaluation and Systems Analysis

SECTION A

ECONOMIC CHARACTERISTICS OF THE RED ROCK WATERSHED AND ITS COMMODITY VALUES

1. Santa Cruz County and the Red Rock Watershed

2. Commodities Produced and their Coefficients

3. Methods of Deriving Commodity Values

4. Secondary Economic Effects and their Multipliers

5. References

SECTION A

ECONOMIC CHARACTERISTICS OF THE RED ROCK WATERSHED AND ITS COMMODITY VALUES

Part 1. Santa Cruz County and Red Rock Watershed

Santa Cruz County is located in the middle of southern Arizona and is adjacent to Mexico. It has a population of about 14,000 people or 11.2 per square mile in its 1,246 square mile area (see Figure 1). About 67 percent of the population is urban, 60 percent is of foreign stock, the medium income is about $4,620 per year with 30 percent receiving less than $3,000 per year. The contribution to the county economy from the various sectors in 1964 are given in Tables 1 and 2, taken from the 1967 County and City Data Book of the U. S. Department of Commerce.

To the north and adjacent to Santa Cruz County lies Pima County which is the center for the Tucson standard metropolitan statistical area. The 1956-1966 county share of retail sales for Santa Cruz was 1.11 percent as compared to 18.54 percent for Pima County. The index 1966 of retail sales growth for Santa Cruz County was the second lowest, 116, of the 14 counties in Arizona (1). On the U. S. County ranking system as developed by the Human Resources Branch, Economic Research Service, Santa Cruz County ranked in the 37th percentile whereas Pima County was in the 24th percentile. This is a five factor rating of counties in an equally weighed composite index (see complete rating at end of appendix). Thus the relative socio-economic status of those counties in the 1st percentile would be the "best" off in the nation and those in the 100th would be "worst" off among the 3,081 counties in the United States.

Tourism and general recreation are important to Santa Cruz County (2). The Nogales area is much more dependent on the recreation tourist than the Tucson-Pima County area to the north. In 1966 the direct dollar volume of business of the recreation tourist was 4.4 percent of the total business activity in Santa Cruz County. The recirculation of this money in the local area is limited and it usually leaves the county relatively quickly. The average multiplier for this money is about 1.40 times the original value (2).

The Nogales area is the stop-over point where vacation traffic converges before crossing into Mexico. It is also relatively close to the population centers of Phoenix and Tucson. Many winter trailer campers (snowbirds) spend two to five days in the area before crossing into Mexico. These campers and the people coming from the Tucson-Phoenix area are creating pressures that represent a growing demand for water based recreation areas. The scarcity of water over much of Arizona concentrates these demands and causes strong competition for allocation of water to various outputs or commodities.

Figure 1. Counties in Arizona

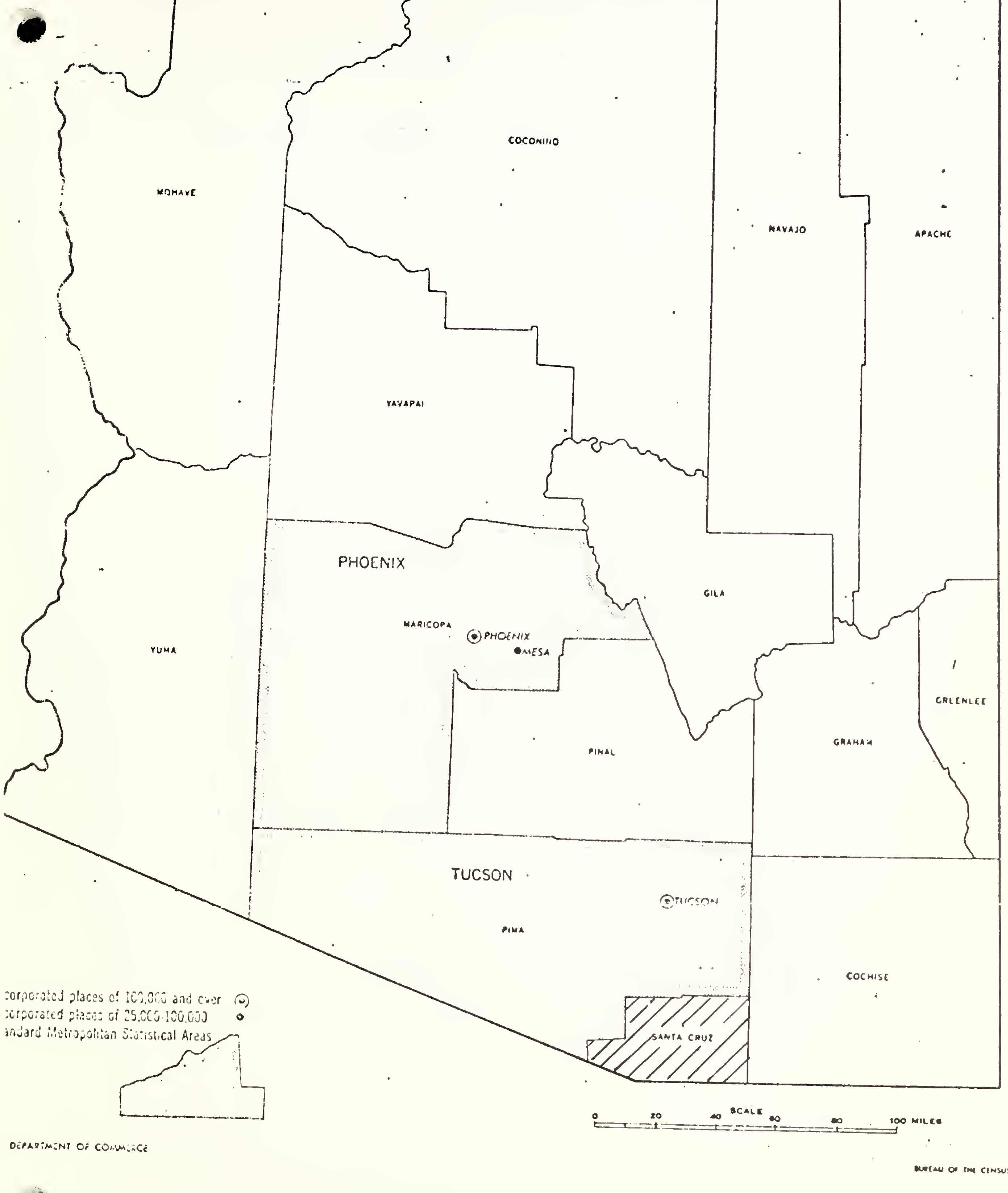


Table 1. Economic Summary Santa Cruz County, Arizona, 1964 1/

	Agriculture (Farms)	Manu-facturers	Wholesale Trade	Retail Trade	Selected Services	Mineral Ind.
Total Number	119	11	44	119	48	n/a
Paid Employees	n/a	85	249	1146	179	n/a
Payroll or Value of Product Sold	$3,873,000 2/	67,000	1,306,000 3/	3,010,000	538,000 3/	n/a
Percent of Total Value						
100	43%	3.0%	14.5%	33.5%	6.0%	n/a

1/ City-County Data Book, U.S. Dept. of Commerce, 1967

2/ Products Sold

3/ Payroll

Table 2. Agricultural Summary Santa Cruz County, Arizona, 1964 1/

Total Number of Farms	Commercial	Part Time	Tenant	Farm Operators Working off their Farm (100 das or more)
119	90	19	10	39

Average Size	Over 10,000 Acres	Under 10 Acres	Total Land (%)
2800 Acres	36	10	42

Total Value of Products Sold	Crops	Livestock Products	Off Farm Income
$3,873,000	$439,000	3,433	$767,000

Total Value	Crops (%)	Livestock (%)	Off Farm (%)
$4,639,000	9.5	74.0	16.5

1/ City-County Data Book, U.S. Dept. of Commerce, 1967

Red Rock Watershed

The Red Rock Watershed lies just east of the town of Patagonia. Red Rock Creek joins Harshaw Creek about a mile above the confluence with Sonomita Creek, which is just above Patagonia. Direct use of water in the local area includes livestock, pumping for ranch use, local irrigation, municipal use by the residents of Patagonia (approximately 650), local businesses, the wildlife conservancy bird sanctuary, a dude ranch, and the Lake Patagonia water recreation complex. The hydrologic analysis shows that of the average amount of water available to the local area, about 17 percent of the volume or 747 acre feet comes from the Red Rock Watershed. The amount of water used and/or consumed locally was determined through water budgets using actual use data and routing the water downstream. Red Rock water was then multiplied by a proportional percentage to determine the contribution by the watershed. The average annual value added directly to the local and immediate area by Red Rock water is $28,943 per year. The total of all outputs plus water has a value added of $49,464 per year. These figures include the analysis of net benefits from the Lake Patagonia recreation complex. A listing of benefits is shown in Table 3.

Table 3. Present Direct Benefits or Value Added by Red Rock Watershed--Average Dollars per year.

Location	Value	Total
Onsite-Combine	$20,521	$20,521
Transitory-Water	---	20,521
Downstream-Water	11,953	32,474
Downstream-Water (Lake Patagonia)	16,990	49,464

The onsite net benefits or value added to the local or immediate area by the Red Rock watershed are listed in Table 4.

Table 4. Present Direct Benefits or Value Added by Red Rock Watershed Outputs--Average Dollars per year.

Item	Benefit/Yr.	Cost/Yr.1/
Hunting		
Big Game	3,459.	0
Small Game	454.	0
Water Fowl	524.	
Forage	17,346	2169.
Wood Fibre	1,180	299.
Mining	n/a2/	n/a
Rock Hounds	354.	
Road Maintenance	0	200
Fire	0	93
Sediment	0	103/
Flooding	0	25
TOTAL	$23,317.	$2796

Net Benefit = $20,521/yr.

1/ Some costs are annual equivalent costs because of their periodic timing.

2/ Exploration is going on in the watershed but its present contribution to the area is unknown. The areas has a past history of mining.

3/ This could be expected to increase to about $270 with Lake Patagonia in operation downstream.

The present average direct net benefit or value added by the Red Rock Watershed per acre foot of water and per acre is shown in Table 5.

Table 5. Present Average Direct Benefit or Value added by Red Rock Water--$/AF and $/AC[1/]

Area	$/AF	$/AC
Without Lake Patagonia	$16.00	$0.67
With Lake Patagonia	38.74	1.70
Lake Patagonia	25.86	1.11

1/ Based on 17,820 AC and 0.043 AF/AC/Yr with average yield of 747 AF/Yr.

It is important to keep clear in mind that the figures shown represent only the "best" available index of dollar worth. Along with this are economic values in terms of value judgements and social worth that often are of more importance. Economic values include all these and need to be expressed as clearly as possible. Further discussion of socioeconomic values not measured by dollars above is given in later sections.

Footnotes for table entitled: U.S. counties ranked according to percentile of five factor index of the relative poverty status of their rural population and the percentile rank of these counties for specified individual indicators of the relative economic status of their rural population

1/ The five factor rank of counties is an equally weighted composite index of the county ranks for each of the five factors specified for columns 1 through 5. The first percentile comprises the highest (best) ranking one percent of all U.S. counties. The 100th percentile contains the one percent of U.S. counties ranking lowest (worst) with respect to the measurement factors being used. Within each percentile counties are arrayed from highest (best) to lowest (worst). For example Nassau County, New York ranks No. 1 among all U.S. counties with respect to the relative socioeconomic status of its rural population as measured by our composite of five factors. At the other end of the array Coahoma County, Mississippi ranks last (worst) among the 3,081 U.S. counties for which the relative socioeconomic status of their rural population was measured using this five factor index.

2/ Number of rural families with less than $3,000 family income, 1959.

3/ Percent of rural families with less than $3,000 family income, 1959.

4/ Percent of rural persons 25 years old and over with less than 7 years of schooling completed, 1960.

5/ Percent of occupied rural housing units in deteriorating and dilapidated condition, 1960.

6/ A ratio of rural persons under 20 years old and 65 years old and over to rural persons 20 through 64 years old, 1960.

7/ Median not reported where base is less than 200 rural farm families.

Developed in the Human Resources Branch, Economic Development Division, Economic Research Service.

Table 5A - Conti..ued

Five factor percentile rank, county and state 1/	Low income rural families, 1959: Number 2/ (1)	Low income rural families, 1959: Percent 3/ (2)	Adult educational level 4/ (3)	Inadequate housing 5/ (4)	Dependency ratio 6/ (5)	Median family income, 1959: All (6)	Median family income, 1959: Rural (7)	Median family income, 1959: Rural farm (8)	Per capita income, 1959 (9)
	Percentile								
37th Percentile									
Cedar, Iowa	61	47	11	47	34	48	42	49	48
Pulaski, Ind.	41	37	30	19	73	45	37	45	47
Harrison, Ohio	44	30	32	59	34	34	28	23	40
Shelby, Ohio	48	24	28	26	74	24	26	30	34
Pocahontas, Iowa	52	43	17	22	66	50	41	50	49
Eddy, N. Dak.	15	48	29	28	79	49	41	56	62
Clinton, Mich.	63	16	12	33	75	15	13	13	31
Goshen, Wyo.	22	35	35	47	61	37	33	21	21
Warren, Ind.	22	28	29	70	51	36	26	25	46
Smith, Kans.	39	62	3	47	49	70	63	64	55
Santa Cruz, Ariz.	8	31	54	66	42	39	33	12	31
McDonough, Ill.	57	50	7	54	31	40	52	50	30
Lake of the Woods, Minn.	13	48	38	28	73	63	54	52	72
Monona, Iowa	48	57	22	21	52	59	58	52	54
Owen, Ind.	36	51	38	20	55	56	54	43	51
Wilkin, Minn.	22	55	18	33	72	50	58	53	65
Franklin, Maine	49	29	14	57	53	44	38	54	52
Davis, Iowa	30	66	13	55	38	64	67	53	61
Noble, Okla.	20	54	31	84	12	54	53	41	30
Gage, Nebr.	66	64	56	7	9	56	66	70	53
Ashtabula, Ohio	80	13	31	32	45	15	11	15	19
Parmer, Tex.	25	28	52	61	35	34	26	20	21
Eau Claire, Wis.	53	23	36	19	71	8	13	30	12
Moody, S. Dak.	33	59	7	11	92	69	62	56	78
Wibaux, Mont.	6	63	36	11	86	69	63	61	73
Kent, Tex.	5	45	42	94	16	49	41	38	40
Palo Alto, Iowa	51	65	10	2	74	66	67	66	69
Woodson, Kans.	24	59	21	36	63	69	62	61	63
Clay, S. Dak.	22	69	3	55	54	53	70	65	52
Edgar, Ill.	60	56	17	40	30	47	54	50	38
Marion, Kans.	51	34	34	37	46	40	32	30	25

Table 5B - Continued

Five factor percentile rank, county and state 1/	Low income rural families, 1959: Number 2/ (1)	Low income rural families, 1959: Percent 3/ (2)	Adult educational level 4/ (3)	Inadequate housing 5/ (4)	Dependency ratio 6/ (5)	Median family income, 1959: All (6)	Median family income, 1959: Rural (7)	Median family income, 1959: Rural farm (8)	Per capita income 1959 (9)
	Percentile								
24th Percentile									
Vigo, Ind.	62	18	36	41	9	22	15	15	17
Prairie, Mont.	5	32	47	4	77	42	34	13	43
Dakota, Nebr.	12	34	25	28	64	26	41	47	39
Grand, Utah	1	4	16	71	73	4	4	7/	6
Grand Isle, Vt.	10	54	46	22	34	65	57	23	58
DeKalb, Ill.	58	22	6	33	46	10	17	38	11
Bonner, Idaho	31	30	13	45	47	39	35	32	41
Jefferson, Ky.	80	4	45	8	28	12	4	8	10
Dickinson, Kans.	40	39	13	34	40	41	44	43	29
Douglas, Kans.	28	27	10	56	44	23	25	29	22
Washabaugh, S. Dak.	2	43	56	3	61	58	50	26	82
Solano, Calif.	51	18	42	54	1	7	23	12	9
Lycoming, Pa.	83	15	24	29	15	23	20	20	19
Berks, Pa.	96	6	49	11	4	12	11	16	8
Sarasota, Fla.	82	33	44	1	5	37	34	36	4
Rich, Utah	5	47	1	19	95	64	56	47	71
Menard, Ill.	24	25	39	41	38	38	30	27	17
San Luis Obispo, Calif.	77	18	37	23	11	15	15	5	11
Coos, Oreg.	58	11	21	59	18	12	12	9	13
Marshall, W. Va.	34	15	46	52	19	25	20	17	37
Union, Oreg.	24	29	20	56	38	23	33	22	22
St. Charles, Mo.	41	9	49	15	53	10	10	20	21
Yankton, S. Dak.	33	76	41	5	12	51	76	78	64
Elko, Nev.	11	24	45	83	4	3	19	35	6
Boone, Iowa	45	35	48	15	23	35	33	37	1
Dawson, Nebr.	32	58	12	28	36	49	61	47	44
Clinton, Ind.	44	25	7	42	49	24	25	26	26
Yolo, Calif.	32	13	55	43	24	6	15	4	7
Pima, Ariz.	71	19	51	20	6	14	9	26	10
Franklin, Kans.	39	54	11	28	36	50	53	49	41
King, Wash.	91	3	7	26	40	2	3	2	2

Part 2. Commodities Produced and their Coefficients

Commodity Coefficients

A commodity is defined as a product produced from a hydrologic response unit or hydrologic area under a given activity. Generally these outputs are benefits, such an example would be camping from the activity of recreation. Many of them can be directly associated with a cost. Other outputs, such as sediment may not have a benefit, but is usually associated with an impact or cost.

Associated with these commodities and/or outputs are coefficients that describe their various characteristics. These are (1) structural coefficients that characterize the rate of output on a perunit area per year basis, (2) right hand side coefficients that show the limits on quantity of the output or available area and (3), value coefficients that are a "best" dollar index of value to describe the benefits, costs or impact of the commodity or output. Depending on how used, they may or may not reflect demand and may or may not vary. These are used in the linear program in present worth form for the entire time stream of benefits and costs.

In the Red Rock economic evaluation ten major project alternatives exist, nine are on the watershed and one is off the watershed. The reason for this is that downstream water needs may not be entirely satisfied by spilling from the dam or by leakage from the reservoir. If there are real deficiencies, an alternative is to augment flows by water yield increase through type conversion. Four areas have been considered for type conversion. Their coefficients are shown separately from the Red Rock Watershed. The Red Rock Watershed and the type conversion evaluation alternatives are therefore two situations of with project and without project evaluations. Within each and between the two, several alternatives as to intensity of development and/or scale or size of development exist as well as location or hydrologic areas to develop.

The following tables 6, 7, 8 and 9 list the commodities, outputs and coefficients for the watershed and the type conversion areas. The form of the coefficients will vary depending on what tools of analysis are to be used in the evaluation. If one of the tools is linear programming, then conversion to a certain basic form will be needed. For a given commodity, a different form may be required where part of it falls under other activities. The form of the coefficient will depend largely on the objectives of an analyses and how the coefficients must be structured in the linear program to give meaningful results. Items that occur periodically or are mixes of varying proportion over time--such as acres of burn, can be converted to average annual equivalent acres to facilitate analysis. The discounted benefit or cost over time will still be the same. Some benefits and costs are incorporated into a per acre figure or a single one time cost and do not appear directly in the final tables. These data and other, can be gotten later as needed to help interpret the analysis and to show the disaggregated components of the final solution or series of solutions.

Table 6. Without the Project Red Rock Watershed Commodities, Outputs, and Coefficients--Average Yearly[1/]

Item	Structural Coefficient per unit area/per year	$ Benefit	$ Cost	Limits or Constraints (Right Hand Side Coef.)
Hunting	0.03/VD/AC/YR	$0.25/AC/YR	0.0	650 VD/YR
Wood Fibre	6.24 CU.FT./AC/YR	0.472/AC/YR	$0.11/AC/YR	15,600 CU.FT./YR
Rock Hounds	0.0027 VD/AC/YR	0.002/AC/YR	0.0	50 VD/YR
Forage	0.33 AUM/AC/YR	1.25/AC/YR	0.15/AC/YR	4615 AUM/YR
Sediment	0.0004 AF/AC/YR	0.0	0.0056/AC/YR[2/]	7.24/AF/YR
Fire	0.003 AC/AC/YR	0.0	0.09/AC/YR	49.6 AC/YR
Flooding	1.0 Floods/YR	0.0	24.64/YR	1.0 Floods
Road Maint.	1.82 AC/MI	0.0	58.00/AC/YR	1.91 MI/YR
Water	0.043 AF/AC/YR	1.70/AC/YR	0.0	747 AF/YR

1/ Some items are a one time initial cost while others are periodic or annual.

2/ This will change to $0.15 now that Lake Patagonia is beginning to fill and will be used soon.

Table 7. With the Project Red Rock Watershed Commodities, Outputs and Coefficients - Average Yearly 1/

Item	Structural Coefficient per unit area/per year	Value Coefficient $ Benefit	$ Cost	Upper Limits on Constraints (Right Hand Side Coef.
Camping	1049 VD/AC/YR	$5119/AC/YR	$2800/AC	80,000 VD/YR
Picnicking	122.8 VD/AC/YR	808/AC/YR	2800/AC	10,700 VD/YR
Hunting	0.422 VD/AC/YR	0.29/AC/YR	0.0	757 VD/YR
Fishing				
Lake	47.6 VD/AC/YR		(See Dam & Ramps)	5957 VD/AC/YR
Camper	629.4 VD/AC/YR	377.64 AC/YR	0.0	48,000 VD/YR
Picnicking	18.4 VD/AC/YR	44.21/AC/YR	0.0	1605 VD/YR
Natural Beauty	4.49 VD/AC/YR	25.49/AC/YR	0.0	700 VD/YR
Wood Fibre	7.18 cu.ft/AC/YR	0.542/AC/YR	0.11/AC/YR	17,940 cu.ft/YR
Rock Hounds	0.003 VD/AC/YR	0.02/AC/YR	0.0	58 VD/YR
Forage	0.33 AUM/AC/YR	1.25/AC/YR	0.15/AC/YR	4,495 AUM/YR
Mining	n/a	n/a	n/a	n/a
Flooding	1.0 Flood/YR	24.65/YR	0.0	1.0 Floods/YR
Dam	1.0 Dam	0.0	472,000	1 Dam
Dam Maintenance	1.0 Dam	0.0	15,000	1 Dam
Fish Stocking & Mgt.	1.0	0.0	4,400/YR	1 Dam
Access Road	1.0 Road	0.0	682,200	1 Road

(cont'd)

ɔle 7. With the Project Red Rock Watershed Commodities, Outputs and Coefficients - Average Yearly 1/

Item	Structural Coefficient per unit area/per year	Value Coefficient $ Benefit	$ Cost	Upper Limits on Constraints (Right Hand Side Coef.
Maintenance	1.0 Road	0.0	568/YR	1 Road
Land	1.0 Ranch	0.0	28,000	1 Ranch
Stock Tank	1.0 Tank	0.0	1200.	1 Tank
Fence	1.0 Fence	0.0	7,725	1 Fence
Supplies (Rec.)	1.0/AC/YR	0.0	22.42/AC	259 AC
Cleanup	1 Man	0.0	4500/Site/Yr	1 Site
Boat Ramp	2 Ramps	0.0	40,000	5957 VD/YR
Std.	1 Ramp	0.0	20,000	4842 VD/YR
Econ.	1 Ramp	0.0	7,000	3600 VD/YR
Camp Road	0.0224 AC/AC	0.0	792.28/AC	259 AC
Maint.	0.0224 AC/AC/YR	0.0	0.82/AC/YR	259 AC
Sediment 2/	0.0004AF/AC/YR	0.0	0.0056/AC/YR	7.24 AF/YR
Fire	0.0068 AC/AC/YR	0.0	0.23/AC/YR	119 AC/YR

1/ Some items such as a dam occur once and are primarily a one time cost.

2/ The cost will now change since Lake Patagonia is filling, it will include the new opportunity cost. The new cost in annual equivalents is $ 0.15/AC/YR. This accumulates as an increasing annuity with time.

Table 8. Without the Project Water Commodity Component for Proposed Type Conversion Areas

Item	Structural Coefficient per unit area/per year	Value Coefficient $ Benefit PW_{40}	$ Cost(1)1/ PW_{40}	$ Cost(2) PW_{40}	Upper Limits on Constraints (Right Hand side constraints)
Water					
(2) Temporal Gulch	0.088 AF/AC/YR	$41.22/AC	0.0	0.0	1535 AC/YR-135.0 AF/Yr
(3) Big Casa Blanca Can.	0.088 AF/AC/YR	62.91/AC	0.0	0.0	547 AC/YR-48.1 AF/Yr
(4) Alum Gulch	0.088 AF/AC/YR	41.22/AC	0.0	0.0	653 AC/YR-57.5 AF/Yr
(5) Harshaw Ck.	0.088 AF/AC/YR	59.48/AC	0.0	0.0	520 AC/YR-45.8 AF/Yr

1/ No initial cost to produce water that occurs naturally, however, actually managing the area has probably an insignificant cost assignable to water.

Table 9. With the Project Water Commodity Component - Net Change in Production of Outputs on Proposed Type Conversion Areas

Item	Structural Coefficient per unit area/per year[1/]	Value Coefficients $ Benefit PW_{40}	$ Cost(1)[2/] PW_{40}	$ Cost(2)[2/] PW_{40}	Upper Limits on Constraints (Right Hand side constraints)
Water					
(2) Temporal Gulch	0.082 AF/AC/YR	$ 35.29 /AC	$46.43/AC	$50.44/AC	1535 AC/YR-125.9 AF/YR
(3) Big Casa Blanca Can.	0.082 AF/AC/YR	53.94 /AC	47.45/AC	49.53/AC	547 AC/YR- 44.9 AF/YR
(4) Alum Gulch	0.082 AF/AC/YR	35.29 /AC	47.57/AC	49.30/AC	653 AC/YR- 53.5 AF/YR
(5) Harshaw Ck.	0.082 AF/AC/YR	51.16 /AC	45.70/AC	48.57/AC	520 AC/YR- 42.6 AF/YR
Fire					
(2) Temporal Gulch	0.048 AC Burn/AC/YR	20.60/AC	3/	3/	73.7 AC/YR[4/]
(3) Big Casa Blanca Can.	0.048 AC Burn/AC/YR	20.60/AC	-	-	26.4 AC/YR
(4) Alum Gulch	0.048 AC Burn/AC/YR	20.60/AC	-	-	26.4 AC/YR
(5) Harshaw Ck.	0.048 AC Burn/AC/YR	20.60/AC	-	-	26.4 AC/YR
Hunting					
(2) Temporal Gulch	0.0011 VD/AC/YR	0.12/AC	0.0	0.0	7.68 VD/YR
(3) Big Casa Blanca Can.	0.0011 VD/AC/YR	0.12/AC	0.0	0.0	2.74 VD/YR
(4) Alum Gulch	0.0011 VD/AC/YR	0.12/AC	0.0	0.0	3.26 VD/YR
(5) Harshaw Ck.	0.0011 VD/AC/YR	0.12/AC	0.0	0.0	2.60 VD/YR

1/ This coefficient represents the additional change or increase with the project (0.088 + 0.082 = 0.170 AF/AC/YR Total with Project).

2/ These costs are discounted present worth costs since they involve initial and periodic costs

3/ There is a net decrease in fire suppression costs and damages including sediment. It is reflected here as a net benefit over previous costs.

4/ This is an annual equivalent per year over 40 years and not actual acres.

Part 3. Methods of Deriving Commodity Values.

Value System

The basic procedure used to show the value of various commodities under the different activities is the Gross National-State-Local Expenditure Method (3). It was modified and adjusted so that values represent only additional costs that would not have been spend otherwise (4). Further adjustments were made to show values that would accrue to the local and immediate area of Patogonia or at least within Santa Cruz County. Other values such as net value of irrigation water for various crops were taken from economics studies of Arizona water (5) (6). Local data was also available in some cases for certain commodities. Most cost data for installing structures, facilities, or maintenance were obtained directly from the Ranger District, Supervisors Office or other local sources. The values used are listed in Table 10.

Cost adjustments were made to bring all sources up to a common base in time. Where costs and benefits occured at various points over time, starting from the initial project construction time, the figures were discounted back to the present. The following key assumptions were made:

1. The present value of a benefit or cost as it is valued today was used over the entire time stream (before discounting) since it is assumed they will rise in about the same proportion over time.
2. No future technological changes were built into the analysis to modify assumption (1).
3. Productivity potentials as obtained from other divisions or functions are assumed correct unless new field data indicates need for revision.

The following table is a summary of the various per unit value of the commodity used in the analysis.

Table 10. Commodity Values and Visitor Day Conversions for the Red Rock Watershed - Patogonia Area.

Commodity	$ Value	Man Days/Visitor Day
Camping	$ 4.88/VD	1.0
Picnicing	6.58/VD	4.0
Fishing		
Boat	11.88/VD	
Camper	0.60/VD	1.0
Picnicker	2.40/VD	4.0
Hunting		
Big Game	6.29/VD	1.0
Small Game	9.08/VD	2.0
Water Fowl	10.48/VD	2.0
Natural Beauty	5.68/VD	2.0
Rock Hounds	7.08/VD	2.0
Ornithology (bird observation)	18.88/VD	2.0
Forage	3.29/AUM	
Wood Fibre	0.74 Cu. Ft.	
Water		
Ranch	4.30/AF	
Irrigation	9.05/AF	
Municipal-Industrial	203.35/AF[1]	
Bird Sanctuary	9.50/AF[2] (see orinthology)	
Dude Ranch	4526.00/AF[3]	
Lake Patogonia	25.86/AF[4]	

1/ This is the weighted annual cost/AF
2/ This based on total dollar value of $46,4[illegible]3/YR ÷ 4890 AF/YR annual flow and 2462 VD/YR use. This value does not reflect the true socio-economic value of a bird sanctuary which protects rare and endangered species of birds. It does, however reflect relative dollar values of water for some purposes of comparison.

3/ Actual use was calculated at about 4.4 AF/YR which because of such a small number compared to returns, makes value/AF high.

4/ Based on actual investment costs, projected use, probable user charges, and inflow - storage data.

As was indicated earlier in a previous section, this is an economic evaluation with this phase of the evaluation based on dollar costs and benefits. Dollar costs and benefits do not necessarily reflect the total economic evaluation that must include social and physical factors also. Perhaps a direct quote from "What is Resource Analysis?" by G.H. Fisher of the RAND Corporation, Santa Monica better states this.

" "While in resource analysis we most often ultimately translate physical quantities into dollars, the real objective is to measure the probable "resource drain" on the economy that would result from various possible future courses of action. Dollars are used merely as a convenient "common denominator," so to speak, for aggregating numerous heterogeneous physical quantities and activities into meaningful "packages" for purposes of analysis and decision"."

Essentially the dollar values used in this analysis represent the expected income that would occur if the various proposed activities were carried out. These are dollars added to the local and immediate Patogonia area.

DEMAND

Present and future need for and value of commodities should be based on demand and supply relationships if the objective of sound natural resource allocation is to be met. Although specific demand studies are not available on the Patogonia area, several studies on recreation and tourism gave useful information to build on (2) (7) (8) (9) (10). Use data by various types of recreation was available from nearly Pena Blanca Lake. This was analysed and adjusted for application to the Red Rock Dam area. Although it has been stated that economically speaking, Arizona's real problem lies in allocating its available water so as to maintain a high rate of economic growth (5), specific mention has also been made of the lowering water tables in the Santa Cruz Basin and the need for allocating more water to recreation and industry as well

as agriculture (11). The Red Rock Watershed and greater Sonoita Creek watershed can help meet these needs in the Santa Cruz Basin by improved and more effective watershed management. The cost of this water must in the end be compared to alternative source costs, if they exist, to determine feasibility.

COMMODITY VALUES

When assembling basic economic data on a commodity, conversions of its per unit area output rate or unit productivity (structural coefficient) to a common denominator are usually necessary. As an example, recreation use is counted in man days, but it is converted to and used in visitor days form by the Forest Service. The characteristics of these commodities or outputs must be known if valid analysis and evaluation of the benefits, costs of, and impacts on the soil and water resource are to be made for the resource manager.

As an example, 8 man days of picnicing per picnic unit per day may equal either 2 visitor days or 4 visitor days, depending on the average length of stay at the unit and average number in the group. The value of the visitor day is also affected by these and other factors.

Illustration:1/

$$1VD = 12 \text{ hours of use}$$

$$8MD \left(\frac{3 \text{ hrs}}{12 \text{ hrs}}\right) = 2 \text{ VD (Average stay 3 hrs)}$$

$$8MD \left(\frac{6 \text{ hrs}}{12 \text{ hrs}}\right) = 4 \text{ VD (Average stay 6 hrs)}$$

$$8MD \div 2VD = 4MD/VD$$

$$8MD \text{ @ } \$1.0/MD = \$8.00$$

$$\$/VD = \$MD\ (4) = \$1(4) = \$4/VD$$

or

$$8MD \div 4VD = 2\ MD/VD$$

$$\$/VD = \$MD\ (2) = \$1(2) = \$2/VD$$

1/ MD equals one man day and VD equals one visitor day - USFS.

Demand, both present and potential, has much influence on values. If there are shifts in average numbers of people per visit, hours stay at site, potential capacity, and actual use over the year, it will affect the total per year use of an area. Factors such as nearness to population centers, other sites available, types of uses, percent from each type of user, seasonal patterns, are other factors that affect demand for facilities. The value of a visitor day is also affected by people from different areas and with different expense levels using the same area. Supply also is important. This involves total acres available for an activity, the intensity of area use (number of picnic units per acre), and duration of the year available for use. This may require that trade offs between various commodities will have to be made by the Resource Manager because users compete for the same acre or funding is limited.

Determining Values

The values used in the economic phase of the analysis were derived from costs and benefits that were adjusted to constant dollars. The figures as used in the linear programming phase of the analysis and other phases were discounted to present worth values. This adjusted everything to one common point in time for comparison and analysis. It also incorporates the whole unit time stream implications into the evaluation, subject to the risk and uncertainties of each time stream. An interest rate of 4 and 5/8 percent was used in the analysis based on the Federal Register Vol. 33, No. 249, December 1968. This is now the official rate for all water project evaluation.

All too often cost-benefit studies are an over emphasis of costs and not enough cost-benefit analysis (14). Analysis that puts over emphasis on money costs or benefits are not meaningful economic evaluations. The social and psychological costs or benefits must be described with the best techniques and tools available. Until the last few years, there have been few advances made in applying rigorous economic analysis to these areas (22). It is not unusual to find that the social and psychological value of a resource outweighs its money value or costs.

Travel Costs - One half the travel cost of the distance traveled specifically for using the Red Rock watershed was applies to money introduced to the area (4). These travel costs were weighted for each commodity by the location and type of each major user group involved with it. Cost per mile was adjusted to type of travel and terrain (15).

Camping - Use data from the Patogonia and Nogales Ranger Districts were analysed for camper characteristics and use patterns. Because of the winter snowbird effect, the actual visitor day per acre use was higher than usual. The structural coefficient used represents the percentage of actual potential capability used per year. The same holds true for certain other commodities, such as picnicking. Total benefits were based on travel costs and other expenditures normally made for the types of campers using the area (8). Value per man day was weighted for types of user and converted to value per visitor day. Cost per acre of camping was based on initial installation cost, annual unit maintenance costs, and sanitation and water costs.

Picnicking - Similar procedures as those for camping were used. The characteristics of the user groups and intensity of use differs considerably from campers, as one would expect. The demand for picnicking in the area is considerably less than that for camping (8). The costs per acre are the same as for camping. Although some differences did exist, they were not relevent enough to show.

Clean Up - One man year of services or $4500 is need to manage the recreation area each year.

Fishing - The warm water fishing values were based on small boat use of the area. The characteristics of the lake, its location to population center, the limitations imposed by the different boat ramp alternatives and the contribution to fishing by campers and picnickers were analysed and evaluated (10) (16). Costs associated with fishing

are the boat ramp costs, the annual fish stocking, the fisheries management and the law enforcement costs. These costs and values were separated as to those costs applying directly to the dam and those fishing benefits from boating, camping and picnicking. About 60% of the campers and 15% of the picnickers were expected to participate in fishing (7) (8) (9).

Natural Beauty - About 156 acres were designated as scenic areas or areas of unusual landscape that would become accessable to viewing by the Red Rock Dam project. Benefits represent the expense money brought into the area by those specifically in the area for that purpose. It is likely that other users of the watershed would derive some of these benefits too (25).

Wood Fibre - The Red Rock Watershed has about 2500 acres of mesquite that is being cut by local users and by commercial cutters largely from Mexico. Benefits include the money spent in the area by the commercial cutters and the savings by local users against the next cheapest market alternative for firewood. Costs are primarily the cost of spraying to kill the trees. Additional benefits not evaluated are gained by the increased ground cover, increased forage, improved infiltration and attendent reduction in erosion that accompanies the effect of mesquite on soils. The suggested spraying sequence to maximize net benefits would be to spray another 1000 acres in 5 to 8 years and the remaining 500 acres in about 15 years. This is based on the projected clearcutting rate and additional spraying about 10 years after clear cut to maintain the areas.

Rock Hounds - These benefits represent money added to the area by travel expenses and other purchases made in the area.

Water Quality - At present water quality from the Red Rock watershed poses no problem. Recreations plans for the proposed dam would include the sanitation appropriate for this type of development.

Forage - The benefits are based on the average local market value per 400 lb. cow after all variable costs such as supplimental feeds, trucking, and etc. have been subtracted out. The cost listed and not subtracted represents the \$0.47 per AUM grazing fee. Because there were periods of no use on one of three allotments, the 40 year period was analysed and converted to annual equivalents to represent annual costs and benefits. The lake surface and recreation area would cause about 10 cows or 130 AUM/Yr. to be displaced. This amounts to about \$429 annually. Alternatives to replace this may exist elsewhere on the watershed, possibly those areas being cleared of firewood.

Hunting - The hunting benefits are based on the money added to the area by the various types of hunting on the watershed. The expenses used reflect adjustments to the local area. Use of the area was based on Ranger District Data and maps and statistics furnished by the Arizona Fish and Game Dept. showing characteristics of the various types of hunter groups (7) (8) (9).

Mining - The watershed and surrounding area has a past history of mining. Presently most activity is confined to exploration due to changing mineral prices and demands. Although not listed, there are probably some present benefits being derived and also costs in the form of impact to the soil and water resource from past and present activities. These at present appear to be negligible.

Flooding - Flooding has occurred from the watershed and adjacent areas due to high intensity storms and some unfavorable hydrologic conditions within watersheds. The 2% and 4% chance storms (50 years and 25 years) were applied to the area over the 40 year evaluation period to obtain

flooding costs or benefits from flood damage prevention if the dam were in. These were converted to annual equivalent costs or benefits (17).

Fire - With the increased use of the watershed because of better access and recreation facilities, fire occurance is expected to increase also. Fire frequency curves were plotted from 1961 to 1969 fire data for Patogonia and Nogales Ranger Districts. Per cent chance occurance versus acres of burn based on twenty acreage classes was used to compare the areas. Adjustments for differences in the use and characteristics of the areas were made and this information was used to plot a future frequency curve for the Red Rock Watershed. The increased costs of fire supression and damages from loss of hunting, forage, and sediment accumulation were then calculated over the 40 year time period. Similar methods were used on the areas proposed for type conversion. However, these areas had an increase in rate of spread but a decrease in cost of supression per acre and a resulting net benefit of about $26 per acre burned (18). This assumes that the prevention of fire from spreading to larger areas and the resulting impacts prevented are worth at least $26 per acre. The impact of flooding and sediment alone may run as much as $4 or $5 per acre over the first 3 years after a fire.

Sediment - Based on the existing rates and future rates at different intensities of activity, the impacts or costs of erosion and the resulting sedimentation from hydrologic areas were calculated for with and without the Red Rock Dam, with and without fire, and with and without type conversion. These were evaluated over the forty year time stream. Since Lake Patogonia is now filling, the primary source of present sediment impact will be on

the lake. If Red Rock Dam is built, the primary impact for the watershed would shift to the dam. Although onsite losses in productivity are important factors, sediment at the dam causes annual losses in surface area that have a high per acre value. This opportunity cost of benefits foregone accumulates yearly as an increasing annuity. A surface acre lost one year is an acre that has a benefit foregone each year after while the project or activity is in operation. Based on other small dams in the southwest, the characteristics of the sites involved, and the rate of sedimentation, a figure of 1/20 of a surface acre lost per acre foot of sediment was used.

Dam - Cost data on initial cost and annual maintenance was supplied by the Arizona Fish and Game Department.

Miscellaneous Costs - These include land purchase costs based on official appraised values and others such as fencing, stock tanks, etc. whose costs were obtained from the Ranger District or other local sources.

Roads - The costs per mile for the three alternative main access roads and campground roads were furnished by the Coronado National Forest. Annual maintenance costs were included in the analysis.

Downstream Water Values - Use of water for ranching, irrigation, municipal-industrial, the bird sanctuary and Lake Patogonia was based on data collected from the records or local users, well pumping cost data, dam inflow and release data, area capacity curves, and water budgets were used as described in previous sections. In some cased, if rates or costs of use were unknown, crop coefficients and per capita or per acre rates for the southwest were used (6) (19) (20). Values per acre foot of water are generally not marginal values, but represent net benefits after variable costs have been substracted. The net benefit was

then divided by the acre feet of water involved in producing the commodity or output.

In the economic evaluation of the Patogonia - Sonoita Creek Bird Sanctuary, the total money value added to the area was about $46,480 per year. Based on the annual flow in acre feet that one can depend on at least 50% of the time, the value of this water is $9.50 per acre foot. At higher rates of reliability, the total annual flow would be less and value per acre foot higher. The average annual flow from the portion contributed by the Red Rock Watershed is about 690 acre feet or a dollar equivalent of about $6560 per year. This is primarily a money value and does not reflect all the social and psychological values derived from the ornithological, ecological, entomological and esthetic experiences received by those who utilized the sanctuary. Nevertheless, considerable value dollar wise is brought into the immediate area. This is due primarily to the higher costs incurred by some user groups who travel considerable distances just to visit the sanctuary and stay overnite in the immediate area. Most of the data on amount of use and user characteristics was obtained from Nature Conservancy Representatives in the Phoenix-Tuscon area. These data were in relative agreement with that obtained from local Patogonia sources.

Net benefits and water value per acre foot at Lake Patogonia are based on initial costs, recreation facilities design, inflow - outflow data and area elevation curves of the dam. The initial investment of about $1,630,000 was amortized over 30 years at 7% and then added to annual variable costs and maintenance to give total annual costs. These were subtracted from the total benefits of the various

types of recreation available, to give annual net benefit. The calculated net value of Lake Patogonia water for recreation was $25.86 per acre foot per year. This figure is higher than the figure of $21.67 calculated for Elephant Butte Reservoir in New Mexico (21).

Type Conversion - The value of water from the conversion sites is based on where it will be used downstream. Total benefits include additional benefits from increased hunting and reduced fire costs due to the project. Costs on the four areas suitable for treatment are based on two treatment methods, plus the initial cost of road construction needed to convert each area. Treatments are based on discussions with the Phoenix office of the Rocky Mountain Range and Forest Experiment Station and the Tonto National Forest. These two units are presently working together on large scale type conversion projects in Central Arizona.

The sequence of treatment proposed for each method is shown in Table 11. Since about 25% of the area at each site is in dense mesquite and oak, it may be feasible to burn only part of the area. Also on some of the steeper topography burning may not be applicable and the alternative treatment of heavy spraying is needed. Spraying twice the first year is recommended to hasten water yield which would increase the discounted value of benefits.

Table 11. Type Conversion Treatment

Sequence (1)Spray and Spray (2) Burn and Spray

YR	Treatment No. 1	Treatment No. 2
1	Spray (Fall & Spring), Seed	Spray (Fall & Spring) Burn & Seed
2	Spray & Hand Spray Remaining trees	Spray & Hand Spray Remaining trees
3	Spray (Maintenance)	Spray (Maintenance)
8	Spray "	Spray "
13	Spray "	Spray "
18	Spray "	Spray "
23	Spray "	Spray "
28	Spray "	Spray "
33	Spray "	Spray "
38	Spray "	Spray "

Value of Water in alternative Uses - Opportunity Costs

The value of the water component of a commodity or output from the Red Rock Watershed was calculated and tabulated in tables (12) (13) and (14). The watershed in this case was treated as one large response area. Also shown are the opportunity costs per acre for putting the resource to use in producing other commodities or outputs. The opportunity price or cost of a resource is the value of the resource in its most valuable manner (12). In some cases the values foregone (opportunity cost) is greater than the net benefits of the present use, in others it is not. This should be looked at from a comparison basis and not as an outright economic indicator of need to convert to alternative outputs (13). Although the value of water per acre may be higher in some alternative uses, the actual benefit per acre may be less. These data can be useful to the Resource Manager in determining trade offs and aiding other resource decisions.

Table 12. Value of Water for General Vegetation and the Opportunity Cost for Water in Alternative Use.

Output or (Commodity)	Water Utilized AF/AC/YR	Commodity $ Value/AC/YR	Water $ Value/AF/YR	Water Utilized Total $ Value/AF/YR
Vegetation (General)				
Water Yield =	0.042	1.63	38.74	
Vegetation transporation=	1.100	1.73 1/	1.57	
Hunting and Sediment Benefits				
Utilized water =	1.142	$3.36		$2.94
Vegetation Removed				
Old water =	0.042	1.63	38.74	
New water =	0.208	8.06	38.74	
Opportunity costs				
Hunting and Sediment		-1.73		
Spraying cost		-2.52 2/		
Utitlized water =	0.250	$5.44 Net Benefit		$21.76
Opportunity Cost =		$2.08	Value Difference =	18.82

1/ Sediment benefit of $1.48/AC/YR plus $0.25/AC/YR hunting benefit

2/ Annual equivalent cost/year. Based on $45.70 over 40 years.

Table 13. Value of Water for Production of Forage and the Opportunity Cost for Water in Alternative Use.

Commodity or Output	Water Utilized AF/AC/YR	Commodity Value $/AC/YR	Water $/AC/YR	Total Value of Water Utilized $/AF/YR
Forage (Grazing)				
Water Utilized				
AUMS	0.0003	1.04	$3,457.00	
Vegetation transportation	1.100	1.73	1.57	
Water Yield	0.042	1.63	38.74	
Utilized water	1.1423	4.40		3.85
Grazing and vegetation removed				
Old Water	0.042	1.63	38.74	
New Water	0.208	8.06	38.74	
Opportunity Cost				
Hunting and sediment		-1.73		
AUMS		-1.04		
Spraying cost		-2.52 1/		
Utilized water	0.250	4.40		17.60

Opportunity costs to convert = 0.0

Value Difference = $13.75/AF/YR

1/ Annual equivalent cost.

Table 14. Value of Water for Production of Wood Fibre and the Opportunity Cost for Water in Alternative Uses

	Water Utilized	Commodity	Water	Water Utilized
Wood Fibre (Firewood)	AF/AC/YR	$ Value/AC/YR	Value/AF/YR	Total Value/AF/YR
Firewood (400 Cu Ft/AC)		0.41		
Vegetation Transpiration 2/ (Hunting & Sediment)	1.100	1.73		
		2.14	1.94	
Water Yield	0.042	1.63	38.74	
Water Utilized	1.142	$ 3.77		
Convert to Forage				$ 3.30/AF/YR
Old Water	0.042	1.63	38.74	
Vegetation Transpiration	1.100	1.73	1.57	
AUMS	0.0003	1.04	3457.00	
Opportunity Cost		-0.41		
Spray to Kill Mesquite		-0.15 2/		
Water Utilized	1.1423	$ 3.84		$ 3.36/AF/YR
Opportunity Cost to Convert to Forage	=	$ 0.17/AC/YR	Value Difference =	$ 0.52/AF/YR
Convert to Bare Ground				
Old Water	0.042	1.63	38.74	
New Water	0.208	8.06	38.74	
Opportunity Costs				
Hunting & Sediment		-1.73		
Firewood		-0.41		
Spraying Cost		-2.52 3/		
Water Utilized	0.250	$ 3.99		$ 15.96
Opportunity Cost =	$ 0.22/AC/YR			
			Value Difference =	12.66/AF/YR

1/ Annual equivalent value per year for midpoint benefit of $12.31/AC converted to annual equivalents on a 30 year rotation.

2/ Annual equivalent cost of present worth cost of $2.17/AC converted to annual equivalents for the 2500 acres to be sprayed over the 40 year period.

3/ Annual equivalent cost/AC over the 40 year period of the evaluation.

Part 4. Secondary Economic Effects and their Multipliers

Secondary Effects

The secondary economic effects are important to an area in that they help to show what happens to money spent in an area and what effect it will have on the local economy. If the local area is highly dependent on importing its goods and services from nearby larger communities, "leakage" will be high and the local turnover of circulation of dollars will be low. Most local economies generally have low total recreation expenditures, low total business multipliers, high leakage rates and a low propensity to invest (23).

A list of multipliers for products of Arizona's industries is shown in Table 15 & 16. These multipliers represent final demand and would likely be too high for some commodities in the local and immediate Patagonia area. These multipliers can be expected to change as the makeup of the economy of Arizona shifts with time.

Table 15

Output Multiplier Effects of a One Dollar Change

in Final Demand for Products of

Arizona Industries (24)

Sector No.	Sector	Multiplier 1/	Rank 2/
1	Meat Animals and Products	1.3045	18
2	Poultry and Eggs	2.0612	2
3	Farm Dairy Products	1.6256	5
4	Food and Feed Grains	1.2395	19
5	Cotton	1.2309	20
6	Vegetables	1.0927	25
7	Fruit and Tree Nuts	1.1681	24
8	Citrus Fruit 1/	1.1718	23
9	Forage	1.0881	26
10	Miscellaneous Agriculture	1.1872	22
11	Grain Mill Products	1.5843	7
12	Meat and Poultry Processing	2.0405	3
13	Dairy Products	2.1606	1
14	Canning, Preserving, Freezing	1.3618	15
15	Miscellaneous Agric-Processing	1.4783	10
16	Chemicals and Fertilizers	1.3688	14
17	Petroleum	1.1972	21
18	Fabricated Metals and Machinery	1.4534	11
19	Aircraft and Parts	1.6196	6
20	Primary Metals	1.9442	4
21	Other Manufacturing	1.4899	9
22	Mining	1.5821	8
23	Utilities	1.3724	13
24	Selected Services	1.4069	12
25	Trade and Transportation	1.3143	17
26	Unallocated Services 3/	1.3404	

1/ Total change in gross output within the Arizona economy induced by a change in delivery of one dollar to final demand by the sector listed.

2/ Multipliers ranked in order from highest to lowest.

3/ Detailed data for allocating the output of the individual components of this sector were unavailable. Therefore, more gross allocation procedures were necessary than for the other sectors. For detailed definitions of the components of this and other sectors see Tijoriwala, Martin and Bower, op. cit.

The effect of different commodities on water intake requirements is shown in Table 16 for the state of Arizona (6).

TABLE 16

DIRECT AND DIRECT-PLUS-INDIRECT WATER INTAKE REQUIREMENTS PER $1,000 OF PRODUCTS DELIVERED TO FINAL DEMAND BY ARIZONA ECONOMIC SECTORS

Sector		Direct Requirement per $1,000 Output (acre-feet)	Rank[a]	Direct and Indirect Requirement per $1,000 Final Demand (acre-feet)	Rank[a]
1	Meat animals and products	.407	8	9.823	10
2	Poultry and eggs	.008	22	20.867	3
3	Farm dairy products	.252	9	18.370	5
4	Food and feed grains	63.042	1	64.988	1
5	Cotton	12.551	3	13.585	5
6	Vegetables	6.413	7	6.545	12
7	Fruits and tree nuts	9.950	6	10.177	9
8	Citrus fruits	11.154	4	11.814	7
9	Forage crops	46.938	2	47.082	2
10	Miscellaneous agriculture	6.408	5	10.493	8
11	Grain mill products	.019	17	19.258	4
12	Meat and poultry processing	.012	18	5.928	13
13	Dairy products	.010	19	9.148	11
14	Canning, preserving and freezing	.043	13	.871	15
15	Miscellaneous agricultural processing	.020	16	2.389	14
16	Chemicals and fertilizers	.030	14	.389	16
17	Petroleum	.020	15	.035	22
18	Fabricated metals and machinery	.003	24	.039	21
19	Aircraft and parts	.004	23	.034	23
20	Primary metals	.187	11	.322	17
21	Other manufacturing	.009	21	.187	20
22	Mining	.147	12	.217	19
23	Utilities	.210	10	.248	18
24	Trade, transportation and services	.010	20	.033	24

a Ranked from highest to lowest according to the values in the adjacent column on the left. Where ties appear, the sectors were ranked on the basis of additional decimal places not published here

Part 5. References

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SECTION B

ECONOMIC EVALUATION AND SYSTEMS ANALYSIS

Preface - Economic Definitions

Economic Evaluation

1. Economic Benefits from the Red Rock Watershed

2. Water Values and Opportunity Costs

3. Economic Benefits from the Proposed Red Rock Dam Alternatives

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ECONOMICS PREFACE

Glossary of Economic Definitions for Natural Resources

6-3-69

(Preliminary Revision)

ECONOMICS

BASIC DEFINITIONS OF TERMS USED IN THE ECONOMIC EVALUATION

ACTIVITY - The use of a hydrologic response unit to produce products. Represents the sum total of all inputs of land, labor and capitol that go into producing a series of products or outputs. Example: Activity - Construction Materials, Inputs - Roads, Logging and Regeneration Systems, etc. that produce the commodity of wood fibre (Trees --→ Lumber & pulp) and other commodities that may occur with it such as recreation, hunting and transportation systems that are either direct benefits or induced benefits under the activity.

ANNUAL EQUIVALENT VALUE - A method that takes a benefit or cost stream whose values vary over time, converts it to a present worth value, then adjusts that figure back to a series of equal fixed annual payments. The present worth of these payments is the same as the original present worth value but is distributed equally over time for comparison purposes.

ASSOCIATED COSTS - The costs of goods and services, over and above the direct project costs, needed to make the immediate products or services of the project available for use or sale. These are costs that must be incurred before all or some of the primary benefits can be realized. Induced costs are a special type of associated costs.

BENEFIT COST ANALYSIS (Cost Effectiveness) Analytical approach to solving problems of choice which requires the definition of objectives and identification of the alternatives that yield the greatest present worth benefits for any given present worth cost. Or if under a singular objective, minimizes the cost to meet the objective.

BENEFIT LOCATION

ONSITE - For each hydrologic response unit or area, the water falling on, flowing in, extracted from by vegetation or for any purpose, yielded from, and/or detained in the soil mantle.

TRANSITORY - (Part I) - Water, whether intermittently or continuously, moving across or through the soil and rock mantle and/or flowing in open channels, between onsite hydrologic response units or areas and the month of the planning and project area watershed.

(Part II) - Water movement and use as in part one, from the mouth of the watershed to the National Forest boundary.

DOWNSTREAM - Water movement and use as in part one, from the National Forest boundary on downstream to its total depletion, or into the sea.

BENEFIT VALUE DETERMINATION POINT - The point where an output or commodity is given its primary benefit value if it is a direct or induced benefit of the project. The point will vary for the same output depending on where and how it is produced and used. These are the benefits that occur to the direct users of the project outputs.

COMMODITY _ Products (outputs) produced from a hydrologic response unit under a given activity.

CONSTRAINTS - A limitation on the commodities production rate, physical inputs used to produce them, land area, budgetary, multiple use guides and others, all used in such a way as to help lead to an optimum solution for the defined objectives.

DECISION MAKER - The Natural Resource Manager, one who makes the management decisions - the District Ranger and the Forest Supervisor.

DIRECT WATER VALUE - Water that is a commodity itself and is used as the prime factor in producing benefits. Water for culinary use is an example. The satisfaction received is primarily from the water and not its use with something else.

ECONOMIC EVALUATION - The practical and systematic analysis of the factors of producing outputs from natural resources assessed in terms of socio-economic values and effectiveness. So designed to aid the Resource Manager in making his Multiple Use Planning and Project decisions.

ECONOMIC VALUES - Benefits in terms of value judgments and social worth as well as a "best" available index of dollar worth.

EVALUATION CRITERIA - Rules or standards to rank the alternatives in order of desirability. They provide a means for weighing cost against effectiveness. Multiple criteria are usually more meaningful than a single criteria. Examples are net present worth, internal rate of return, benefit-cost ratios, income distribution, and risk and uncertainty.

INDUCED BENEFITS - Those benefits caused by increases in the production function of some other product through backward or forward linkages with the direct benefit or the factors that produce it. They usually occur immediate to or within the direct benefit area. They are "spillovers" or "external economies" that are the result of a project or its output causing an increase in the production or production function of some other producer. An example would be an increase in a bee keepers honey production caused by the farmer down the road increasing the size of his apple orchard, which made more pollen available to the keepers bees.

INDUCED COSTS - These are "negative benefits" or "external diseconomies" or impacts that occur as a result of a project causing a decrease in the production of some other output or its production function. Loss of fishing recreation due to insufficient water releases from a new dam, to sustain downstream fish habitat and fisheries is an example.

INPUTS - Resources utilized to achieve selected outputs, i.e., to accomplish an effort (project) and includes money, manpower, land, material, equipment and other resources.

INTERNAL RATE OF RETURN (I.R.R.) - Is that rate of interest where future cost and benefits discounted to the present are equal. Projects may be ranked by their internal rate of return for decision making. The internal rate of return is also referred to as the marginal efficiency of capital.

INTERNAL AND EXTERNAL ALTERNATIVES - Internal alternatives are other combinations of natural resource inputs that will meet the planned objectives. This could mean using other inputs or mixes, or doing the project somewhere else on the area or other areas to get the outputs at a lower cost or less impact.

External alternatives would be meeting the demand for an output through means outside the agency. Examples in water production would be desalinization, pumping and piping from other areas, recycling, reclaiming, etc. The purpose of comparing alternatives is to find the "best" way to maximize net benefits in attaining the objectives.

MANAGEMENT OBJECTIVES - The objectives that the area multiple use management plan is based on to meet national, regional and local demands for natural resource outputs, subject to the potentials, hazards and suitabilities of the soil and water resource base.

OPTIMUM - Economic optimum would be the "best" combination of inputs that produces a combination of outputs or commodities that maximize the net value of the planned objectives. The optimum may be to maximize the net benefits from the objectives (benefits minus costs) or maximize benefits, or minimize costs. However, one cannot maximize benefits and minimize costs at the same time.

The economic optimum is a different optimum than the physical optimum in most cases. Unless stated otherwise - optimum will be based on economic criteria.

OPTIMUM DEVELOPMENT - The optimum development of an area or a resource is that combination of scope and type of development which, when measured by economic, social, and other factors, best achieves the objectives of the development.

PRESENT WORTH - The series of benefits or costs that would accrue from a project over its life, discounted back to present time. It could be described as that amount of money one would have to deposit now, at a given interest rate, to accumulate to a known future value.

PRIMARY BENEFITS - (direct benefits) - The value of the change in the existing or new production of outputs that accrues to the direct user of the project. They are increases or gains in the value of goods and services which result from conditions with the project as compared to conditions without the project. Induced benefits are a special type of primary benefits.

PRIMARY COSTS - (direct cost) - The series of direct costs that include the value of goods and services necessary for installing or building the project, and the operation and maintenance and repair that occurs overtime with the project.

PRODUCTION FUNCTION - ""A production function is a schedule (or table or mathematical equation) showing the maximum amount of output that can be produced from any specified set of inputs, given the existing technology or "State of the art." In short, the production function is a catalogue of output possibilities"" - C. E. Fergeson. It gives the relationship between rates and combinations of inputs and the rate of output.

PROJECT ECONOMIC LIFE - That period of time, estimated by economic, technical, and social factors, after which the costs of continuing the project will exceed the benefits to be expected from a continuation of the project.

SECONDARY BENEFITS - Oversimplified, they are the net increases in production or income changes for all benefits not directly associated with the project. This net increase is based on income expansion with the project as compared to that without the project. Secondary benefits from the standpoint of economic effectiveness and efficiency are not recognized in the primary evaluation criteria. If they are part of the main project objectives, they may become a form of primary benefits.

SECONDARY COSTS - All those costs not directly tied to or associated with producing the goods and service resulting from the project.

MAXIMIZATION OF NET BENEFITS - Net benefits are maximized when the scale of development is extended to the point where the benefits added by the last increment of input (i.e., an increment of size of a unit, and individual purpose in a multiple purpose plan, or a unit in a comprehensive plan) are equal to the cost of adding that increment of scale - this reflects the law of deminishing returns. This point is usually below the point of maximum physical yield.

MODEL - "A model is a simplified, stylized representation of the real world which abstracts the cause - and - effects relationships essential to the question studied. The means of prepresentations may range from a set of mathematical equations on a computer program to a purely verbal description of the situation, in which intuition alone is used to predict the consequences of various choices. In systems analysis, the role of the model (or models, for it may be in appropriate or absurb to attempt to incorporate all the aspects of a problem in a single formulation) is to estimate for each alternative, the costs that would be incurred and the extent to which the objectives would be attained" - E. S. Quade, The RAND. Corp.

Models are developed for a number of reasons. Generally, however, a model is used for understanding, prediction or control. A descriptive model shows how various elements of a system or environment interact or relate to one another. A predictive model,in addition to being descriptive of a system, relates certain input conditions to the system with specified outputs which designate the predicted conditions or status of the real system that the model represents. A decision or control model, on the other hand, plays a role in maintaining the system in an optimal or satisfactory state. The Federal Budget, for example, is a type of control model designed to coordinate the diverse spending activities of thousands of United States governmental units in this country.

MULTIPLIER - The change in economic activity resulting from a change in investment. Various types of multipliers exist to measure this impact. In general use they represent the direct and indirect coefficients of total change in input requirements as a result of a one dollar change in final demand for a product or output.

NET BENEFITS - Net economic and or social benefits from the activities and commodities produced from an area. Simplified, it is usually the present worth value of primary benefits minus the present worth value of primary costs.

NET PRESENT WORTH - Present worth value of benefits minus the present worth value of costs.

OPPORTUNITY COST - The value of the benefits foregone or the "measurable advantages foregone" as a result of the rejection of the best alternative use of a resource. It should usually be subtracted from the project benefits or they will be overstated. Most of us have to pick and choose: If we choose to have some more of this, we must forego some of that. The choice of one thing eliminates the opportunity to choose another because productive resources are limited relative to all the things that the members of society would like to do with them. The cost of the new item may be considered the loss of the opportunity to spend that resource for other purposes. Elimination of one product in favor of another would require subtracting out the benefits of the old product from the new, to identify the real benefit from the new product. If not, new benefits will be overstated.

SPILLOVER-SPINOFF - Is defined as, "An economy (a benefit) or diseconomy (a cost) for which no compensation is given by the beneficiary or received by the loser. Timber cutting is some cases without hydrologic design may produce an induced benefit from water increase and an induced cost from increased sediment depositing in a downstream reservoir.

SUB-OPTIMIZATION - Is the selection of the best alternative solution or course of action which pertains to a sub-problem but is only part of the overall problem or objective. The best solution to a sub-problem may not be compatible to the solution to the overall problem or objective.

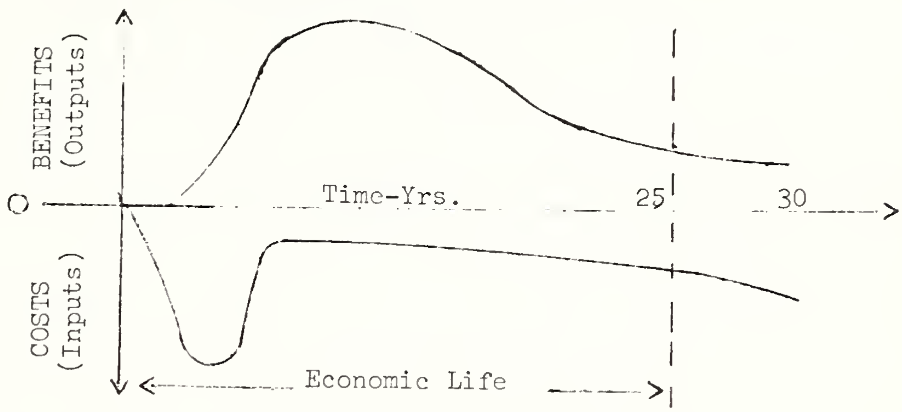
SUNK COST - Defined as cost expended in the past. Costs which have been expended in the past are simply not relevant to the question, "What will it cost in the future to acquire a future capability?" We must be careful to exclude "sunk" cost. No matter how "unfair" it may seem, we should not include the past costs, say for older systems, regardless of how much money is involved. They usually occur due to technological obsolesence or an over-estimate of the economic life of a project or an installation within it.

TESTING OUTPUT MIX SENSITIVITY - Examining the optimum output mix to see how changes in the constraint functions or coefficients would change the optimum solution.

TIME STREAM OF BENEFITS AND COSTS

The series of all the benefits and costs of a project as they occur on a year by year basis from the time a project starts until and end of its economic life.

Figure 1. Time Stream of Project Benefits and Costs: Benefits and costs are both the same at 25th year.

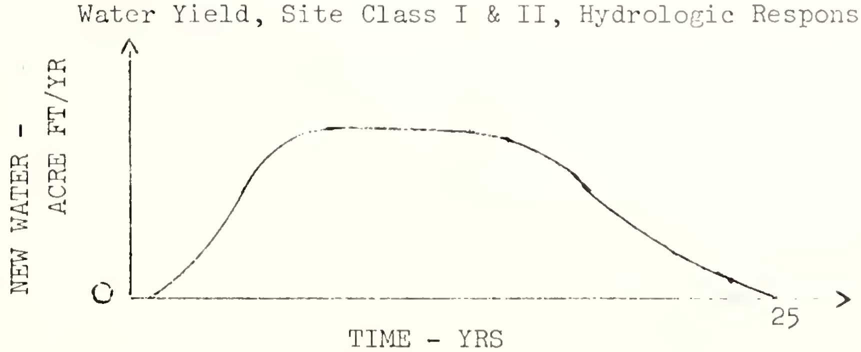


It represents the grouping of all commodity benefits into one aggregate benefit curve and all costs into an aggregate cost curve. These two times streams are then economically evaluated to provide key data for the decision maker. Each commodity under an activity could have its own time stream.

TRANSFER PAYMENTS -Are the increase in the welfare or economy of one area at the expense of the welfare or economy of another area. Examples are: social insurance programs that are not self-supporting, price supports, new industries in an area that could have gone to another area, etc. In may cases they may be a form of secondary benefits.

UNIT PRODUCTION TIME STREAM - The shape over time of an output for a given level or intensity of input. This is usually on a given site, at a given input or management intensity (activity level) and on a per unit area per year basis or per unit per year. The output or benefit stream usually has an attendant input or cost stream.

Figure 2. Unit Production Time Stream: Clearcut Ponderosa Pine Water Yield, Site Class I & II, Hydrologic Response Units 6 to 15.



WATER EQUIVALENT COMPONENT VALUE - The water that is used in producing a commodity and the resulting value of this water in that use.

WITH AND WITHOUT PROJECT - An evaluation should be based on the net results of what would happen with the project versus what would happen over the same period without the project - it is not a before and after comparision. In some cases an improvement in the area or some other activity will produce outputs or increase outputs even if the specifically planned project and its activities hadn't occurred. This must be considered in the economic evaluation as current information and techniques best allow. If not, benefits may be considerably overestimated.

SECTION B

ECONOMIC EVALUATION AND SYSTEMS ANALYSIS

Part 1. Economic Benefits from the Red Rock Watershed

The net primary dollar value added per year from the commodities produced from the Red Rock Watershed are shown in table 1. Appendix IX table 4 gives further breakdown as to onsite benefits and costs if needed. These commodities and net benefits projected over a forty year timestream along with changes that current information indicates, give the present worth of benefits and costs without the Red Rock Project (see table 2). These net benefits represent the discounted onsite values over a forty year time-stream and the downstream offsite proportion of values attributable to the Red Rock Watershed. The present worth values of without the project are substracted from the present worth of with the proposed project values to determine what the local and immediate area gain or loss in values may be (1). This is discussed in detail in Part 2.

The breakdown of benefits by onsite-transitory and downstream locations are shown in table 3. The contribution to the National Economic Sector by the outputs of Red Rock Watershed on a local and immediate area basis is shown in table 4. The same type of benefit breakdown and listing would be useful under the with the project alternatives when the resource manager reviews the proposed alternatives prior to making his resource management decisions (2) and (3).

Table 1. Without the Project - Annual Net Primary and Secondary Value of Commodities Produced from Red Rock Watershed and Its Contribution to Downstream Benefits

Commodity	Net Primary Value	Multiplier	Net Secondary Value
Hunting	$ 4,438/YR	1.3	5,769
Forage	$ 15,177/YR	1.3	19,730
Wood Fibre	$ 881/YR	1.2	1,057
Rock Hounds	$ 354/YR	1.3	460
Mining	$ N.A.	1.6	N.A.
Water			
Ranching (Misc.)	$ 22/YR	1.1	24
Irrigation	$ 506/YR	1.2	607
Municipal	$ 3,050/YR	1.3	3,965
Ornithology-(Bird Sanctuary)	$ 6,564/YR	1.3	8,533
Dude Ranch	$ 1,810/YR	1.2	2,172
Lake Patogonia	$ 16,990/YR	1.3	22,087
	$ 49,792/YR		64,404/YR
-Nonseparable Costs	-328/YR		-328/YR
Total/Yr	$ 49,464/YR		$ 64,076/YR

1/ (19) Arizona Review, February 1967.

Table 2. Without the Project - Present Worth of Benefits and Costs Expected to Accrue from the Red Rock Watershed Over the Forty Year Time Period 1/

Commodity	\$Benefit P.W.$_{40}$	\$Cost P.W.$_{40}$	\$Net P.W.$_{40}$
Hunting	80,247	0	80,247
Forage	357,770	39,213	318,557
Wood Fibre	21,433	5,425	16,008
Rock Hounds	6,399	0	6,399
Natural Beauty	-	-	-
Flood Damage	0	397	-
Roods	0	3,615	-
Fire	0	1,681	-
Mining	na	na	na
Sediment	0	4,880	-
	\$465,849	\$55,211	

Net P.W.$_{40}$ = \$410,638

Downstream

Other uses	\$216,085
Lake Patagonia	\$307,140

Net P.W.$_{40}$ = 523,225

Net P.W.$_{40}$ = \$933,860

1/ Discounted to present values (1969) at a rate of 4-5/8%

Table 3. Without the Project - Primary Benefits from Red Rock Watershed - Water and Other Commodities

Location	Value-$/YR	Total-$/YR
Onsite (All Combined)	$20,521	$20,521
Transitory (Water)	---	20,521
Downstream (Water)	11,953	32,474
Downstream (Lake Patogonia)	16,990	49,464

Table 4. Without the Project-National Economic Sector Values - Primary and Secondary Value of Commodities Produced from Red Rock Watershed

National Economic Sector[1]	Primary Value - $/YR	Secondary - $/YR
Agriculture		
Crops	$ 528	$ 631
Livestock and Livestock Products	$15,177	$19,730
Manufacturing		
Non Durable Goods	$ 881	$ 1,057
Selected Services	$33,206	$42,986
Mining	NA	NA
Nonseparable Costs	$ -328	$ -328
TOTAL	$49,464/YR	$64,076/YR

1/ Based on City and County Data Book, Dept. Commerce, 1967.

In evaluating programs and projects only primary benefits are usually included in the evaluation criteria. However, if, improving the social-economic well being of all or specific sectors of the areas population is also an important mission of the program or project, then secondary benefits must be carefully evaluated. Secondary benefits and multipliers for the Santa Cruz-Southern Arizona area are shown in tables 1 and 4. Input - output studies done on outdoor recreation and other natural resources shown that for the small communities, the secondary effects or multipliers may be relatively small (4) (5) (6) and (7). Much of this is due to the fact that smaller population areas are less self-sufficient and must import many of their goods, causing money to leave the area relatively quickly (3). The industries that have been found to respond directly to these types of programs and projects are the agricultural and selected services - local utilities, equipment, service and repair and grocery sales (4).

Part 2. Water Values and Opportunity Costs

The hydrologic analysis provided the water runoff data to determine how much and when the Red Rock water entered the Sonoita Creek drainage system. Based on actual use data, routing, evaporation coefficients and consumptive use coefficients as described in Section A, a downstream water budget was developed for use of Red Rock water (see table 5). The dollar worth of value added by this water in production on new areas is shown in table 6. As can be seen in table 5, some of the water is reused so that the down-stream demands are met with less water than each individual requirement would take if supplied from separate drainage systems. Much of this water may be in the form of subsurface flow because of the high storage capacity

of the creek beds and their ability to transport water through the sand and gravel medium. If the proposed Red Rock Dam project were to prevent the 747 acre feet from reaching downstream users, then the benefits foregone from this water would represent an opportunity cost to be subtracted from benefits of the dam. This opportunity cost would amount to about $523,220 over the 40 year time stream of project evaluation. Benefits from spilling over the dam could average about 364 acre feet per year. If 50% of this were utilized downstream, the opportunity cost could be reduced by $89,410 or more. Natural leakage from the reservoir and water from type conversion would also reduce this cost. Calculations of the value of water in alternative uses were made to determine if and what potential benefits may exist in other uses (see table 7). Data from the water budgets on the various subwatersheds was analysed to derive the amount of water used to produce a commodity. From this a value was calculated for the water equivalent component of the commodity. This value reflects the dollar portion of the benefits and the dollar value of the opportunity cost foregone. It does not reflect all the social and physical values that are part of the total value of the commodity and its water equivalent component.

In interpreting the value of water in alternative uses, the commodity value per acre and not the total value of the water utilized may be the more important factor. Some alternate water uses that have high per acre foot value have lower values on a unit area basis.

Table 5. Average Year Flow Water Budget of Red Rock Watershed Downstream Water Use 1/ - Acre Feet

Use	Total Requirement -AF	Red Rock Water Component-AF	New Red Rock Water-AF	Red Rock Water Consumed-AF	Red Rock Water Return Flow-AF	Outflow Downstream 2/ -AF
Red Rock Outflow	0	0	0	0	0	747
Ranching	5	5	5	5	0	742
Irrigation	320	56	56	48	12	694
Municipal & Industrial	85	15	3	3	12	691
Evaporation	n/a	1	0	1	0	690
Bird Sanctuary	4,890	690	690	0	690	690
Dude Ranch	4.4	0.4	0.4	0.4	689.6	689.6
Evaporation	n/a	33	33	33	657	657
Lake Patogonia	7.650	657	657	-	-	-

1/ Budget based on field data on use, size of facilities, population, pumping data, and water use coefficients for agriculture and municipalities.

2/ Most of this may be in the form of subsurface flow.

Table 6. Present Direct Benefit or Value Added by Downstream Use of Red Rock Water -$/A.F. and $/AC [1]

Area	$/AF	$/AC
Without Lake Patagonia	$16.00	$0.67
With Lake Patagonia	38.74	1.70
Lake Patagonia	25.86	1.11

1/ Based on 17,820 AC and 0.043 AF/AC/YR with average yield of 747 AF/YR.

It is important to keep clear in mind that the figures shown represent only the "best" available index of dollar worth. Along with this are economic values in terms of value judgements and social worth that often are of more importance. Economic values include all these and need to be expressed as clearly as possible. Further discussion of socioeconomic values not measured by dollars above is given in later sections.

Table 7 — Value of the Water Component for Various Commodities on Outputs and their Opportunity Costs for Conversion to Alternative Uses.[1/]

Commodity or Output	Water Utilized AF/AC/YR	Commodity Value $/AC/YR	Opportunity Cost $/AC/YR	Total Value of Water Utilized $/AF/YR
General Vegetation	1.142	3.36		2.94
Vegetation Removed	0.250	5.44	2.08	18.82
Forage	1.142	5.44		3.85
Vegetation Removed	0.250	3.36	0.0	17.60
Wood Fibre	1.142	3.77		3.30
Convert to Forage	1.142	3.84	0.17	3.36
Vegetation Removed	0.250	3.99	0.22	12.66

1/ Benefit and cost details shown in tables 11, 12, and 13, Section A, Part 3 - **Value of Water in Alternative Uses.**

Part 3. Economic Benefits from the Proposed Red Rock Dam Alternatives

The proposed Red Rock Dam project presents a series of possible alternatives. Each has a number of activities associated with it, and each activity has commodities being produced under it and the commodities require inputs for their production (see Figure 1). The idealized example in Figure 1 shows in simplified form, some of the alternatives to be evaluated.

Differenct levels of project economic evaluation exist, they are: (1) The Total System Level (2) The Project Level and (3) The Commodity Level. It is not until we reach the "system level" that we know if we are actually improving the socio-economic well being of those in the project area or taking values away or just shifting money around to arrive at the same net value as before. The with the project versus the without project evaluation at the System Level is of prime concern in developing an optimal solution within the alternatives and objectives sought by the resource manager (1) (3) (8) and (9). A level of analysis and evaluation below this is a sub-optimum level. Specifically, this would be evaluation at the Project Level and the Commodity Level. The discounted time stream of benefits at these levels may cover the costs of the project or the benefits of an individual commodity may cover its costs, yet the overall project costs or opportunity cost of benefits foregone in the project area may not be covered (see Table 13). If subsidization of benefits is an objective because of the socio-economic needs of an area, evaluation at the proper level is important. This information provides part of the key data needed by the resource manager to determine which alternative "best" meets the objectives. The steps of evaluation as outlined above are shown in Figure 2.

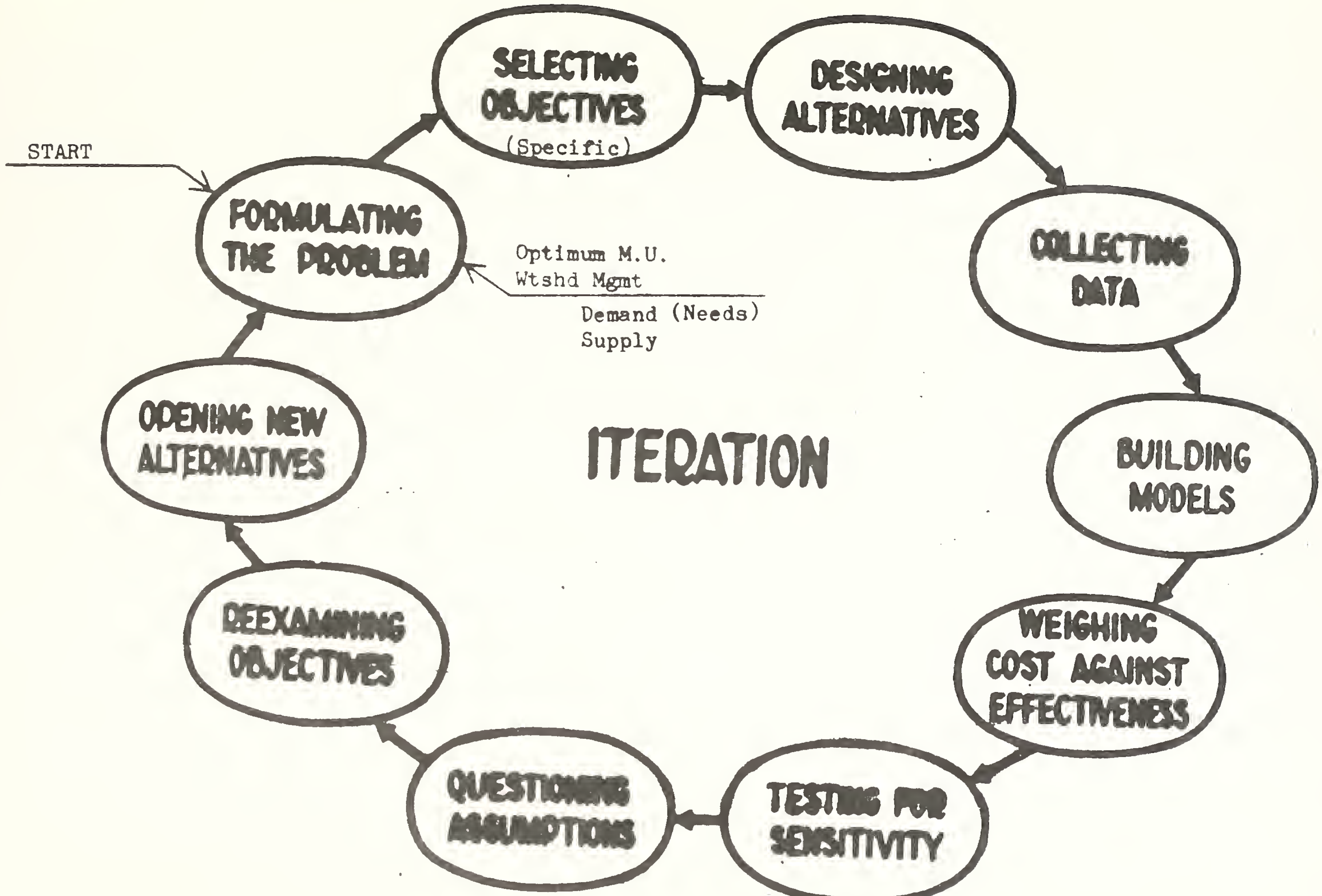


FIG. 1A - THE KEY TO ANALYSIS - ECONOMICS AND WATERSHED MGMT. SYSTEMS (1)

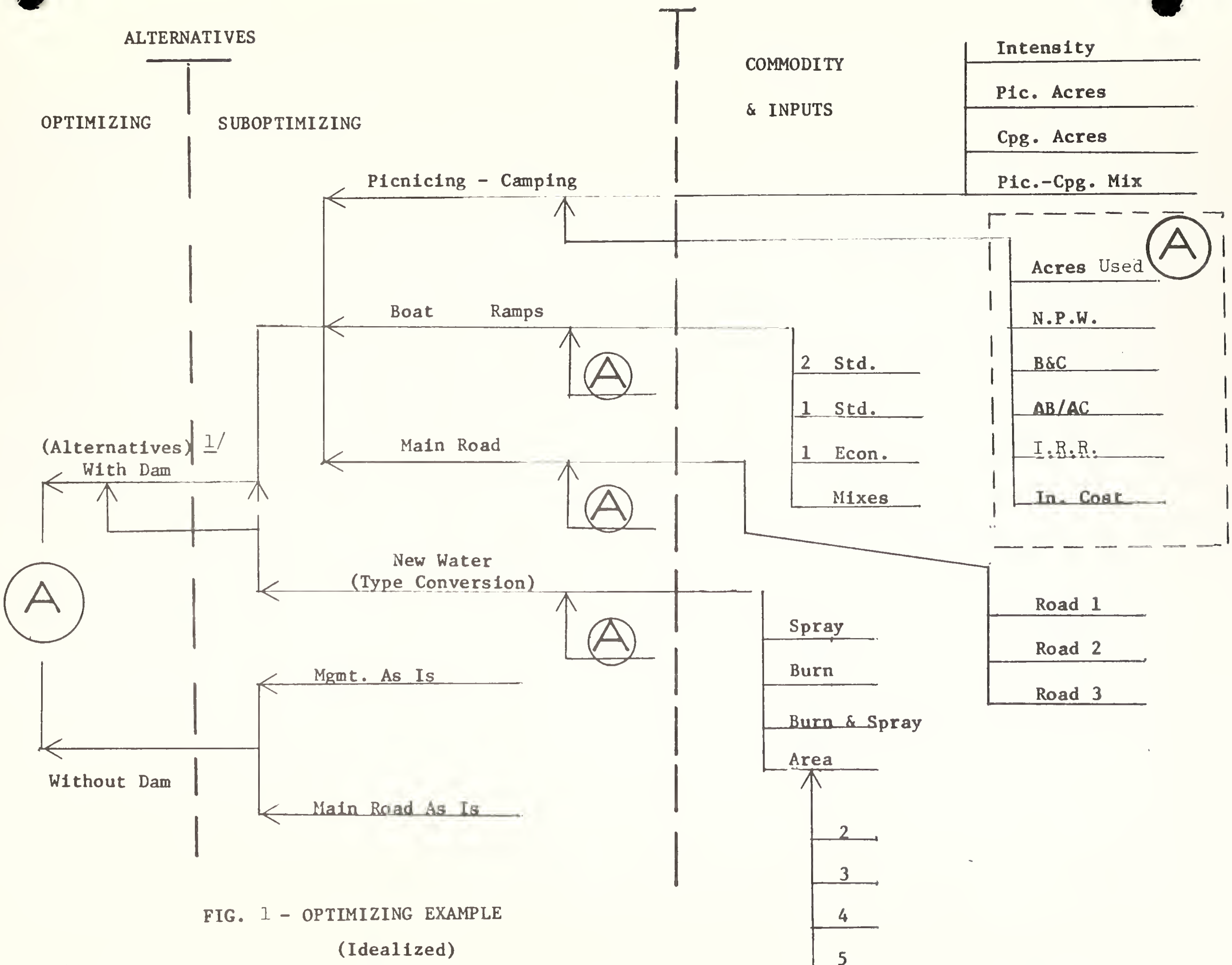
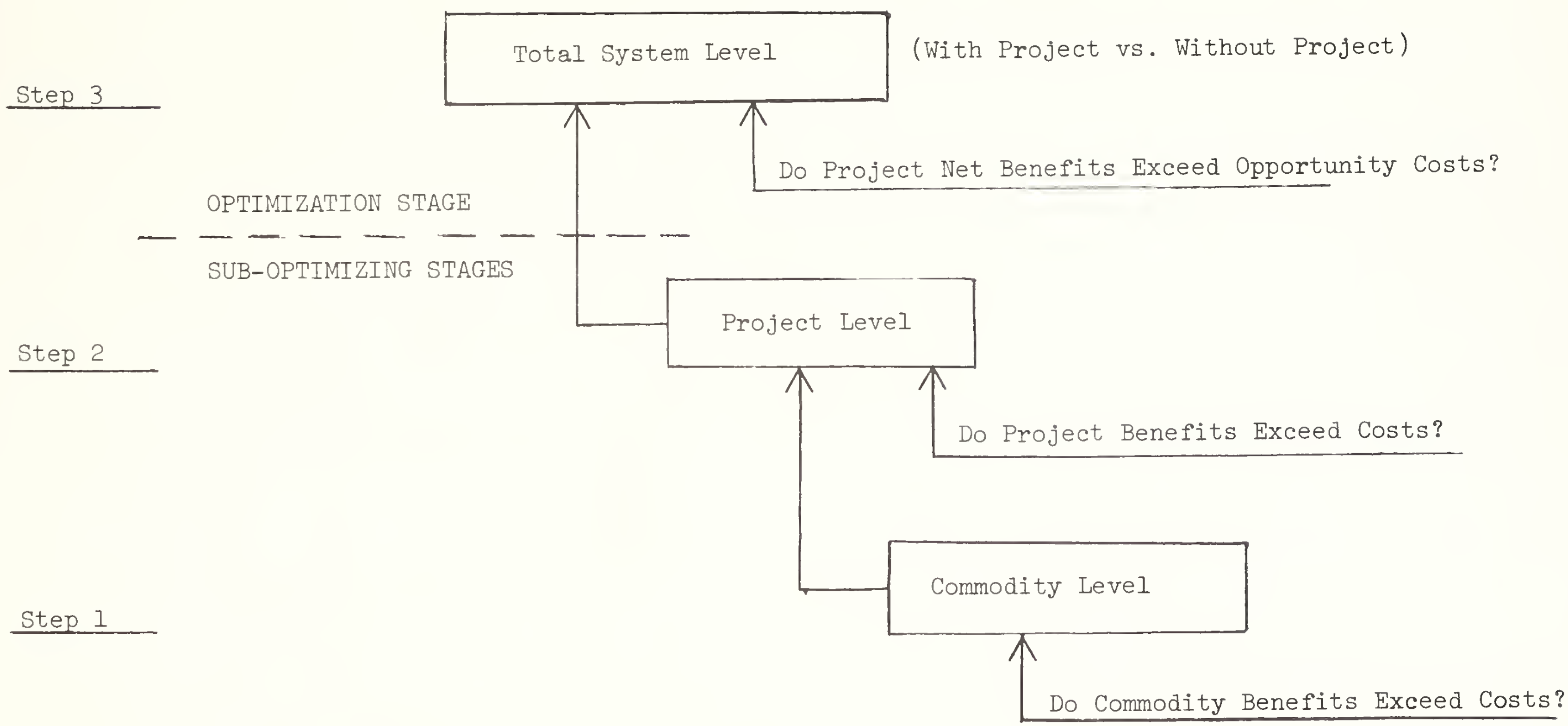


FIG. 1 - OPTIMIZING EXAMPLE

(Idealized)

1/ Application of economic evaluation.

Fig. 2 Steps in Socio-economic Evaluation of Projects over their Economic Life.



In arriving at the expected demand for various commodities from the Red Rock Watershed and the proposed dam complex, the effects of Lake Patagonia and reservoirs in the Central Arizona project were considered. These demand limits and other coefficients are found in Section A.

The present worth of benefits and costs were calculated for with and without the project conditions over the forty year economic life of the project. These figures are shown in Table 8. Included in this table are the opportunity costs and the alternatives of main access roads and boat ramps. The alternatives under picnicking and camping are shown separately and are brought into the total system level of evaluation with the road and ramp alternatives. Part of the analysis was done by linear programming, lack of time and certain data did not permit a complete L-P analysis to be made. A series of tables and figures were set-up to show the present worth of benefits and costs for the various alternatives and the initial costs associated with them (see Tables 9, 10, and 11). Most of the evaluation of alternatives is presented in acres form with Table 12 and Figure 3 set-up to convert acres to visitor days.

The various levels of evaluation one passes through in going from the suboptimization stage to the optimization stage are shown in Table 13 and 13A. This table is an example whose and product is shown in the iso-product net present diagrams of figures 4 through 12. Nctice in Table 13 that at the <u>commodity level</u> a commodity may have a positive net benefit for a given scale of acres, but there may be a negative net benefit at the <u>project level</u> and a more negative net present worth at the <u>total system level</u>. Commodities and inputs in a sense lose their identity at the project level. If the

demands exists, a certain scale of development must be reached before a positive net benefit at the with and without project evaluation (system level) can be shown. Subsidization would be necessary to operate below a positiive net benefit at any given level. If maximizing net present worth of benefits is part of the objectives, than a negative present worth under a given alternative would not be acceptable to the resource manager. In interpreting and using figures 4 through 12, a desired acreage or equivalent visitor day per year of picnicking and/or camping is chosen first. Then, by locating the common point of intercept of the two on the net present worth line or a line parallel to it, gives the expected net present worth of benefits. Either camping or picnicking could be held constant and the other varied to arrive at various net present worth benefits. Once benefits are known, reference can be made to figure 14 which gives initial costs for a given total acreage. Although not reflected in the iso-benefit lines of net present worth as calculated, one could expect some curvature in the lines, as costs should be less, up to a point, for either picnicking or camping as scale of development increased.1/ The scales stop at 76 and 87 acres because this is the estimated point where further development would actually reduce the net present worth of benefits.

A partial list of picnicking and camping net present worth benefits at the commodity level was given in table 13. These can be calculated for any combination using the following formula:

1/ Iso-benefit and iso-product lines are the same thing as used in this analysis. Any intercept of two points that louches one of these lines has the same net present worth value.

Formula for Calculating
Picnicking and Camping Benefits

$$\$ \text{ Net P.W.} = B_1 X_1 + B_2 X_2 - B_3 (X_1 + X_2)$$

Where: B_1 = Net present worth camping benefits/acre = \$77,096.00

X_1 = Acres of Camping

B_2 = Net present worth of picnicking benefits/acre = \$9,887.30

X_2 = Acres of picnicking

B_3 = Present worth of installation and maintenance/acre = \$1297.40

Table 8 Present Worth of Benefits and Costs with Alternatives over the Forty Year Time Period (Camping and Picnicking Alternatives Not Included)

Item	With Dam $P.W._{40}$			Without Dam $P.W._{40}$		
	$Benefit	$Cost	$Net P.W.	$Benefit	$Cost	$Net P.W.
Dam	——	498,016				
Land	——	28,000				
Stock Tank	——	1,200				
Fencing	——	7,725				
Fisheries Mgmt.	1/	70,643				
Sediment	——	45,248			4,880	
Fire	——	4,077			1,681	
Roads	——	(see alternatives)			3,615	
Hunting	88,520	0 2/		80,247	0	
Forage	351,987	38,822	313,165	357,770	39,213	318,557
Wood Fibre	24,651	5,425	19,226	21,433	5,425	16,008
Rock Hounds	6,970	0	6,970	6,399	0	6,399
Natural Beauty	66,229	0	66,229	——	——	——
Flood Damage	397	0	397	0	397	——
Subtotal Onsite	538,754	699,156	——	465,849	55,211	——
Net Benefits $P.W._{40}$			-$160,402			$410,638

Table 8 (cont'd) Present Worth of Benefits and Costs with Alternatives over the Forty Year Time Period (Camping and Picnicking Alternatives Not Included)

Item	$Benefit	$Cost	$Net P.W.	$Net P.W.
With vs. Without Onsite				
Net Benefits = (-$160,402)-($410,638)= -$571,040 3/				
Downstream				
Other Uses	Opportunity Cost	-216,084		216,085
Lake Patagonia		-307,142		307,140
		-$523,225 4/		$523,225

Alternatives	$Benefit	$Cost	Net P.W.
Main Access Road			
(1) Corral Canyon		$692,373	
(2) Red Rock Ck.		519,261	
(3) Harshaw Ck.		461,570	
Boat Ramps			
2 Standard	1,178,814	40,000	1,138,814
1 Standard	938,170	20,000	919,170
1 Economy	692,842	7,000	685,842

1/ These benefits will vary with type and number of boat ramps used. Other fishing benefits are included in picnicking and camping which are alternatives in themselves with various scales of development.

2/ Some wildlife management and law enforcement costs are incurred but are probably small relative to other costs. Specific figures were not obtained.

3/ Does not include picnicking and camping alternatives.

4/ This is an opportunity cost because of benefits foregone downstream if no Red Rock water reaches downstream. Water budgets show an average spill of 365 acre feet per year once the dam fills. Some natural leakage is expected also. If at least half of this were utilized downstream, opportunity costs would be reduced by at least $89,000.

Table 9 — Present Worth Cost of Road & Boat Ramp Alternative Combinations - Dollars

Access Road	Boat Ramp: 2 Std.	1 Std.	1 Econ.
(1)	$1,387,283	$1,367,283	$1,354,283
(2)	1,214.171	1,194.171	1,181,171
(3)	1,156.480	1,136,480	1,123,480

Table 9 A. — Present Worth Benefits of Boat Ramp Alternative and Onsite Activities

	Fishing Benefits	Ramp Costs	Net Benefits [1/]
Boat Ramp			
2 Std.	$1,178,814	-40,000	$1,138,814
1 Std.	938,170	-20,000	918,170
1 Econ.	692,842	-7,000	685,842

[1/] Does not include fishing benefits from picnicing and camping.

Table 10. Recreation Onsite Initial Costs
Red Rock Dam - Dollars/Acre or Unit

Item	Cost[1/] $/Unit	$/Acre
Boat Ramp		
2 Standard	40,000	-
1 Standard	20.000	-
1 Economy	7,000	-
Picnic Unit	2.000	2,800
Camping Unit	2,000	2,800
Camping Road	-	792.28

1/ Actual undiscounted costs

Table 11 — Installation Costs for Picnicing and Camping Development - Dollars

Total Acres	Installation Cost - Dollars [1/]
10	$ 35,920
20	71,770
30	107,770
40	143,690
50	179,610
60	215,540
70	251,460
80	287,380
90	323,300
100	359,230
110	395,150
120	431,070
130	467,000
140	502,920
150	538,840

[1/] Includes $2800/Acre including water and sanitation at 1.4 units/acre plus campground roads at $792/acre of camping or picnicing area.

Table 12 — Conversion of Scale of Development to Visitor Days/Year for Camping or picnicing

Scale of Development-Acres 1/	Picnicing	Camping
5	614	5245
10	1228	10,490
15	1842	15,735
20	2456	20,980
25	3070	26,225
30	3684	31,470
35	4298	36,715
40	4912	41,960
50	6140	52,450
60	7368	62,940
70	8596	73,430
76	9332	79,724 3/
80	9824	83,920
87	10683 3/	91,263
90	11052	94,410
100	1228	104,900

1/ Approximately 1.4 camping or picnicing units per acre were used.

2/ Actual use was calculated at 1049 VD/AC/YR camping and 123 VD/AC/YR picnicing.

3/ Calculated limit on demand.

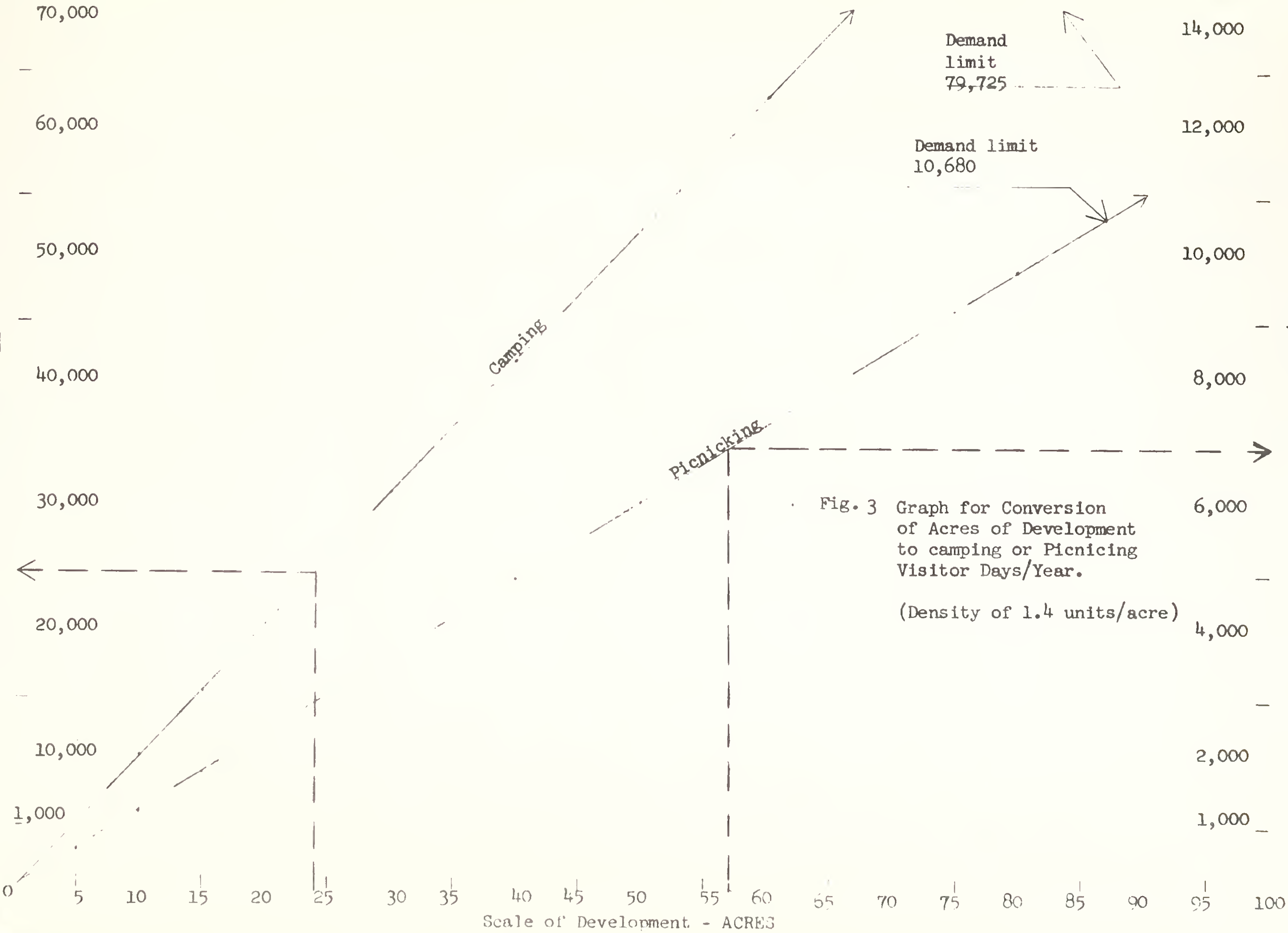


Fig. 3 Graph for Conversion of Acres of Development to camping or Picnicing Visitor Days/Year.

(Density of 1.4 units/acre)

Table 13 Net Present Worth of Benefits Added to Patogonia Area by Proposed Red Rock Dam Project - Dollars (Includes: Access Rd (1), 1 Std. Boat Ramp, Onsite Benefits, and Opportunity Costs).

				SUB-OPTIMIZATION STAGES		OPTIMIZATION STAGE
Picnicing		Camping				
AC	VD/YR	AC	VD/YR	Commodity Land $Net $P.W._{40}$	Project Level $Net $P.W._{40}$	Total System Level (with vs without) $Net $P.W._{40}$
		0	0			
32.6	4000	0	0	280,680	346,075	- 587,788
40.7	5000	0	0	350,742	416,137	- 517,726
48.8	6000	0	0	420,546	485,941	- 447,922
0	0	14.3	15,000	1,084,133	1,149,528	215,665
0	0	28.6	30,000	2,168,266	2,233,661-	1,299,798
0	0	43.0	45,000	3,252,350	3,317,745	2,383,882
20.3	2500	14.3	15,000	1,259,133	1,324,528	390,665
40.6	5000	28.6	30,000	2,518,167	2,583,562	2,518,167
61.0	7500	43.0	45,000	3,602,350	3,667,745	2,733,882

Table 13A Sample Calculations at Various Evaluation Levels -

$ Net Present Worth

Given: 1 Std. Ramp, Access Rd. 1, Onsite Benefits (except picnicing and camping)

Scale of Commodities:

32.6 Acres of Picnicing

0.0 Acres of Camping

Net Present Worth Benefits
= $280,680

Net P.W 40 Commodity Level = $280,680

Net P.W 40 Project Level

$280,680
+ $65,395 (Rd.(1) Cost + Ramp 1 Std. N.P.W. + Onsite Benefits N.P.W.)

SUB-OPTIMIZATION STAGES $ 346,075

- -

Net P.W.40 Total System Level (With vs without)

OPTIMIZATION STAGES

$346,075
- $933,863 (Opportunity Cost)
- $587,788

Fig.4 Iso-product Lines of Dollars Net Present Worth Added to the Patagonia Area by the Proposed Red Rock Dam Recreation Complex at Various Scales of Camping and Picnicing.

ALTERNATIVE - With and Without Project Comparison-Optimization Stage

Includes:

Access Road (1)
1 Std. Boat Ramp
Net Change in Onsite Benefits
Downstream Opportunity Costs

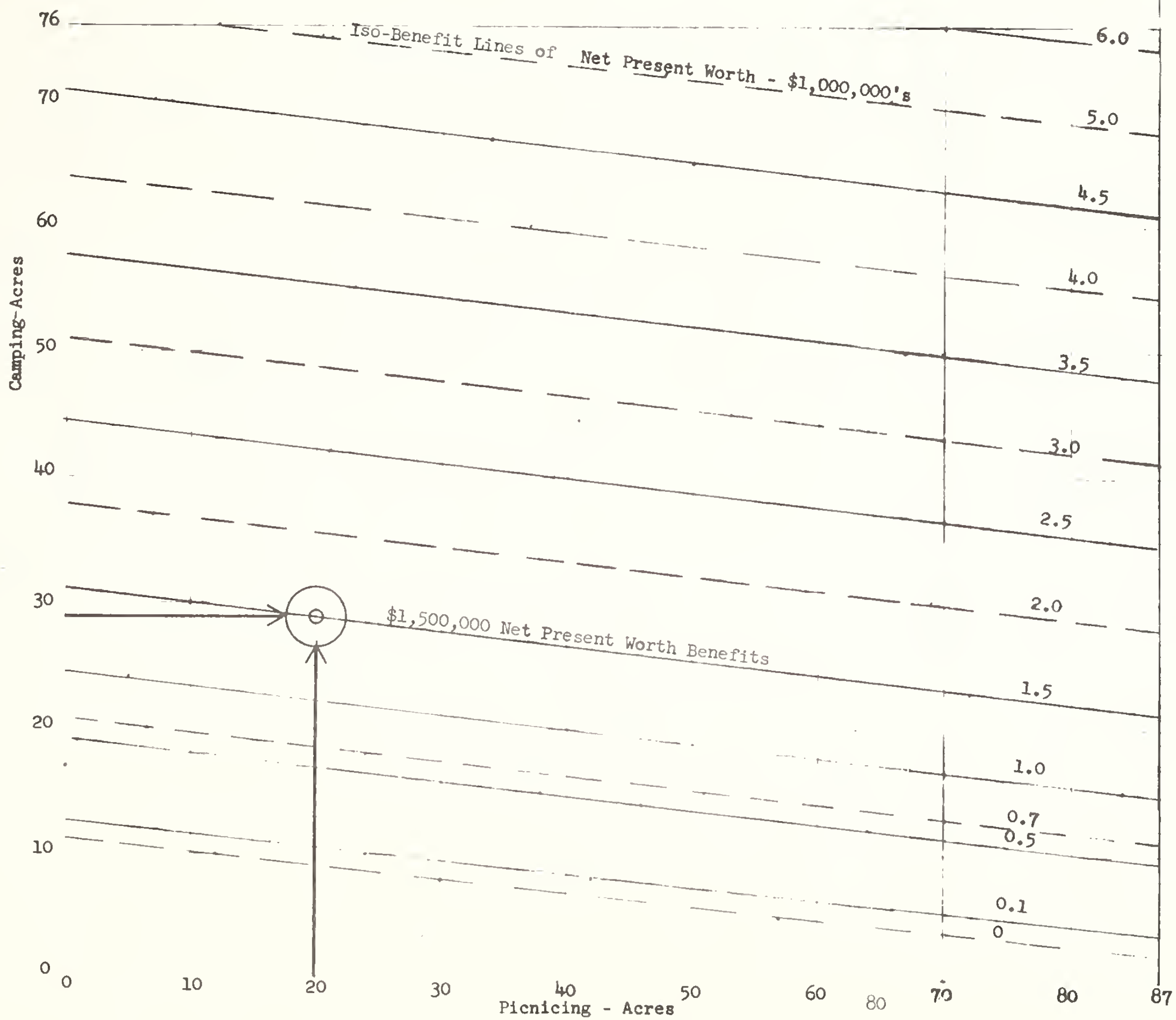


Fig.4A Initial Cost of Picnicing and Camping Development - Dollars per acre. 1/ Includes: Unit Cost/Acre Recreation Road Cost/Acre

1/ A unit density of 1.4 units/acre was used.

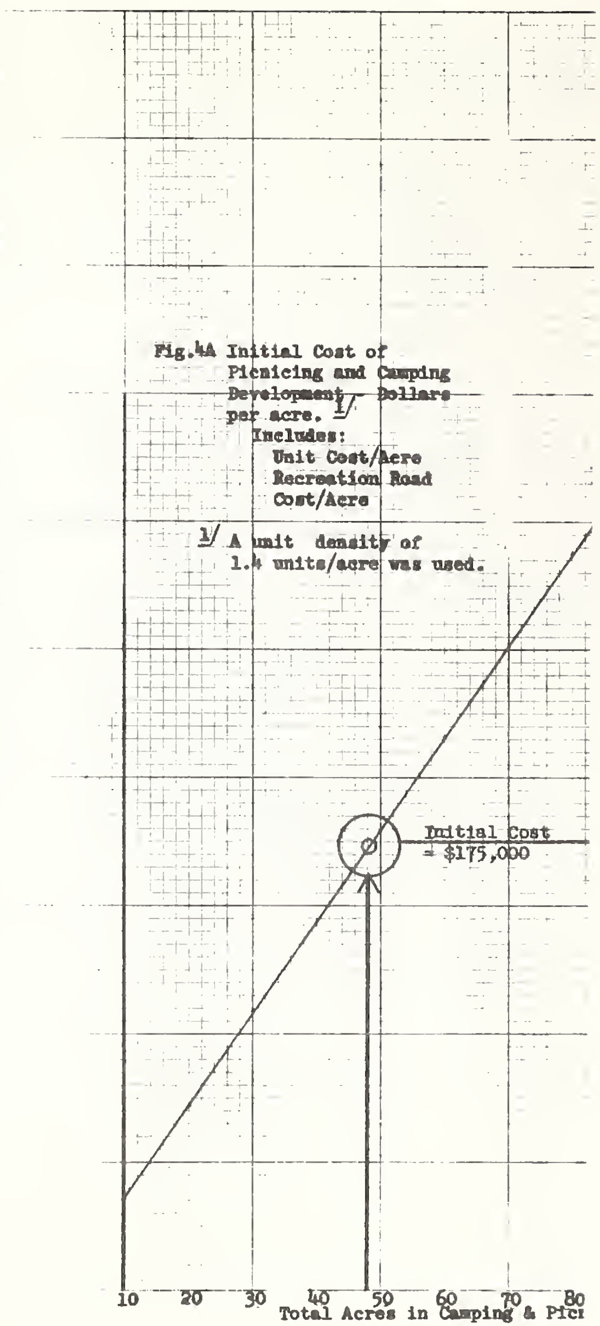


Fig. 5 Iso-product Lines of Dollars Net Present Worth Added to the Patagonia Area by the Proposed Red Rock Dam Recreation Complex at Various Scales of Camping and Picnicing.

ALTERNATIVE - With and Without Project Comparison-Optimization Stage

Includes:

- Access Road (2)
- 1 Std. Boat Ramp
- Net Change in Onsite Benefits
- Downstream Opportunity Costs

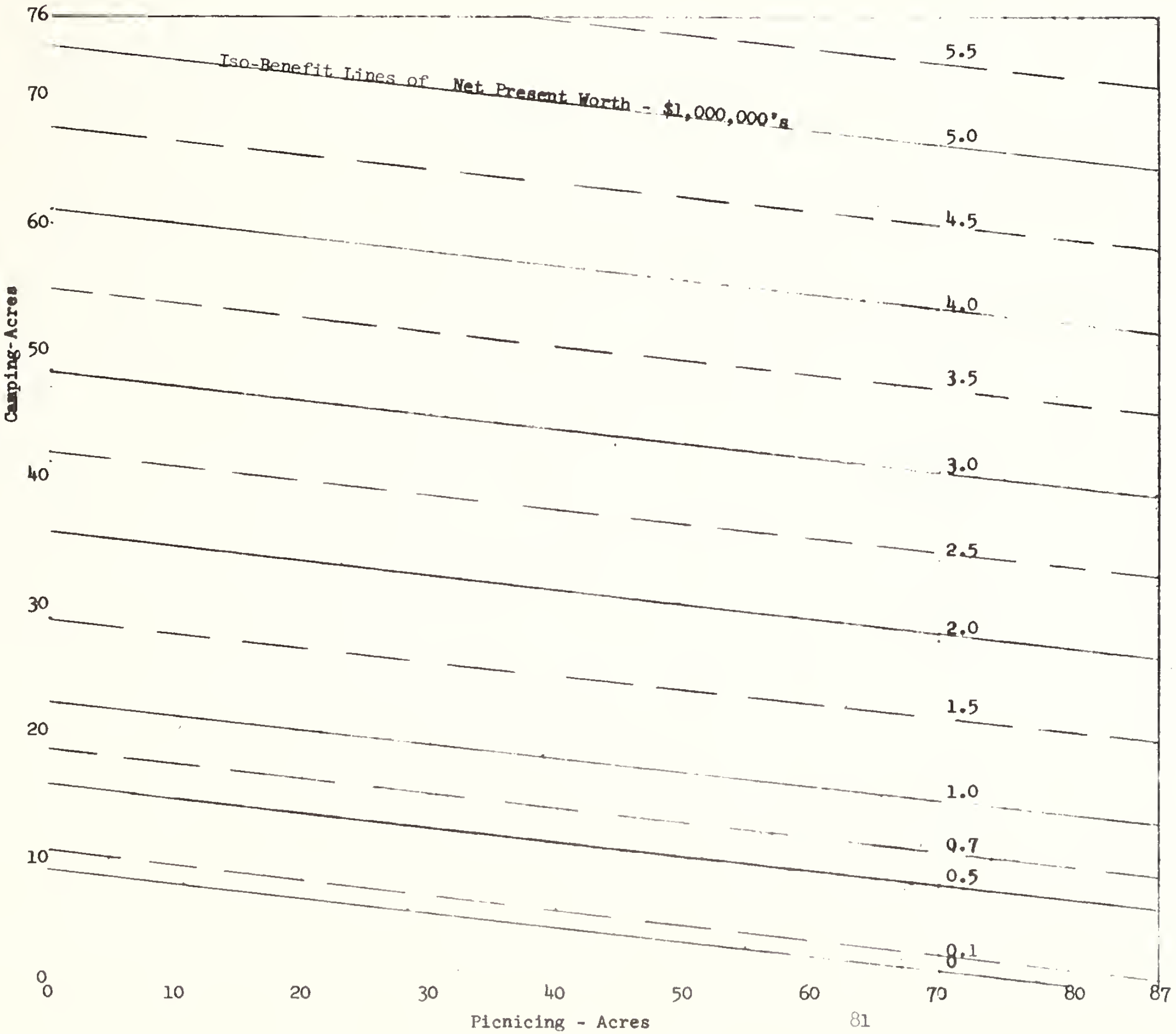


Fig. 6 Iso-product Lines of Dollars Net Present Worth Added to the Patagonia Area by the Proposed Red Rock Dam Recreation Complex at Various Scales of Camping and Picnicing.

ALTERNATIVE - With and Without Project Comparison-Optimization Stage
Includes:
- Access Road (3)
- 1 Std. Boat Ramp
- Net Change in Onsite Benefits
- Downstream Opportunity Costs

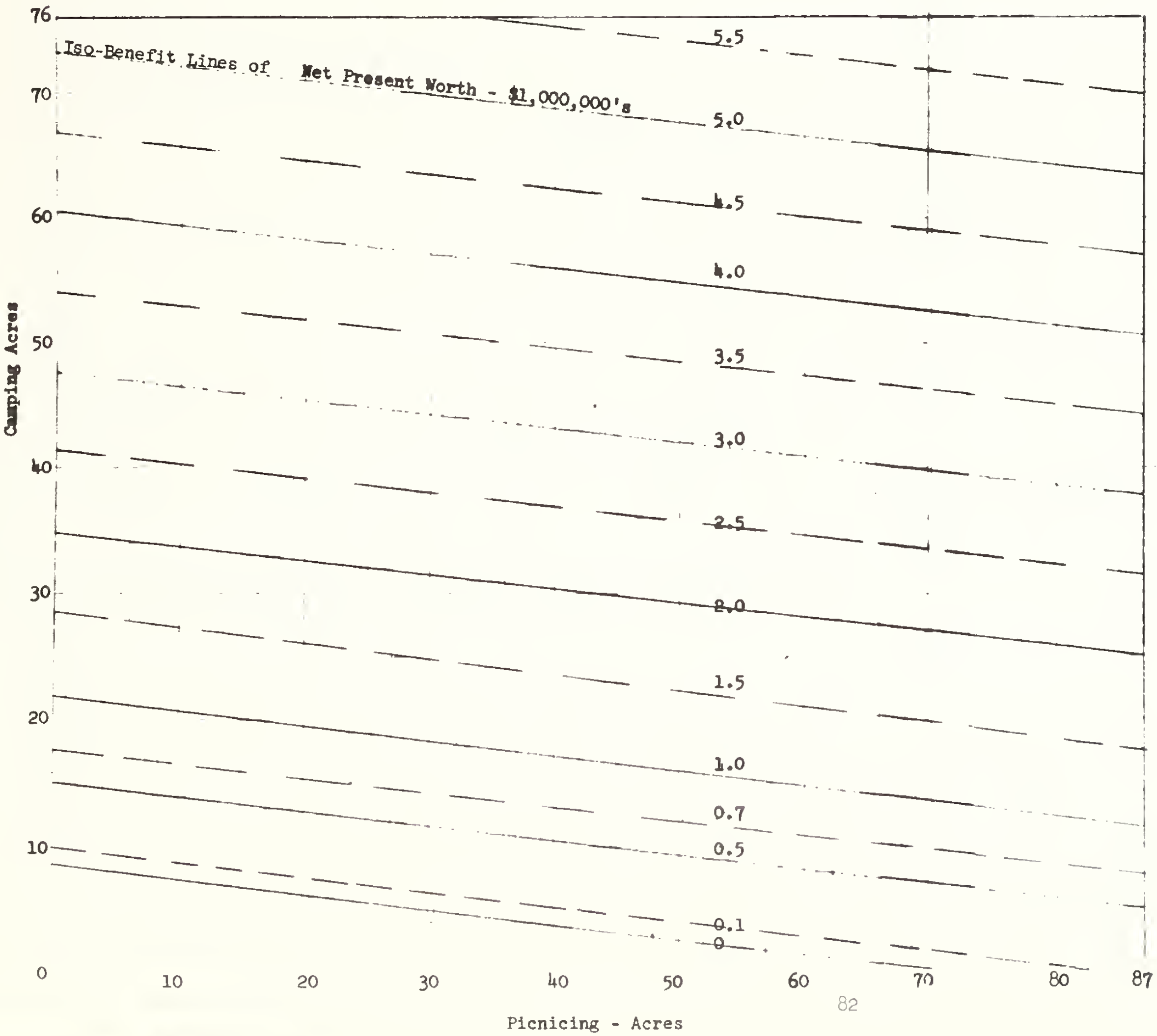


Fig. 7 Iso-product Lines of Dollars Net Present Worth Added to the Patagonia Area by the Proposed Red Rock Dam Recreation Complex at Various Scales of Camping and Picnicing.

ALTERNATIVE - With and Without Project Comparison-Optimization Stage
Includes:
- Access Road (1)
- 2 Std. Boat Ramps
- Net Change in Onsite Benefits
- Downstream Opportunity Costs

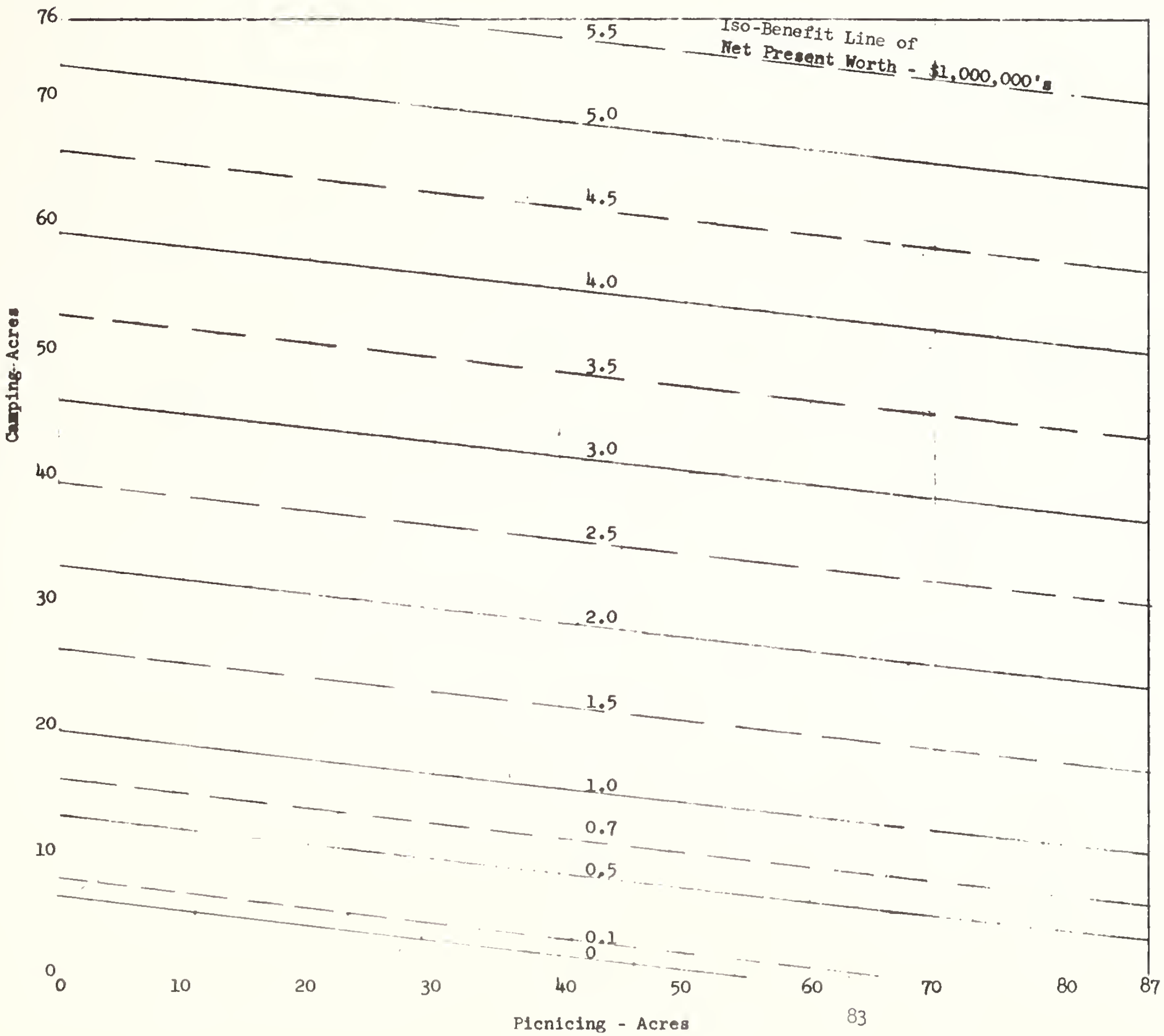


Fig. 8 Iso-product Lines of Dollars Net Present Worth Added to the Patagonia Area by the Proposed Red Rock Dam Recreation Complex at Various Scales of Camping and Picnicing.

ALTERNATIVE - With and Without Project Comparison-Optimization Stage
Includes:
Access Road (2)
2 Std. Ramps
Net Change in Onsite Benefits
Downstream Opportunity Costs

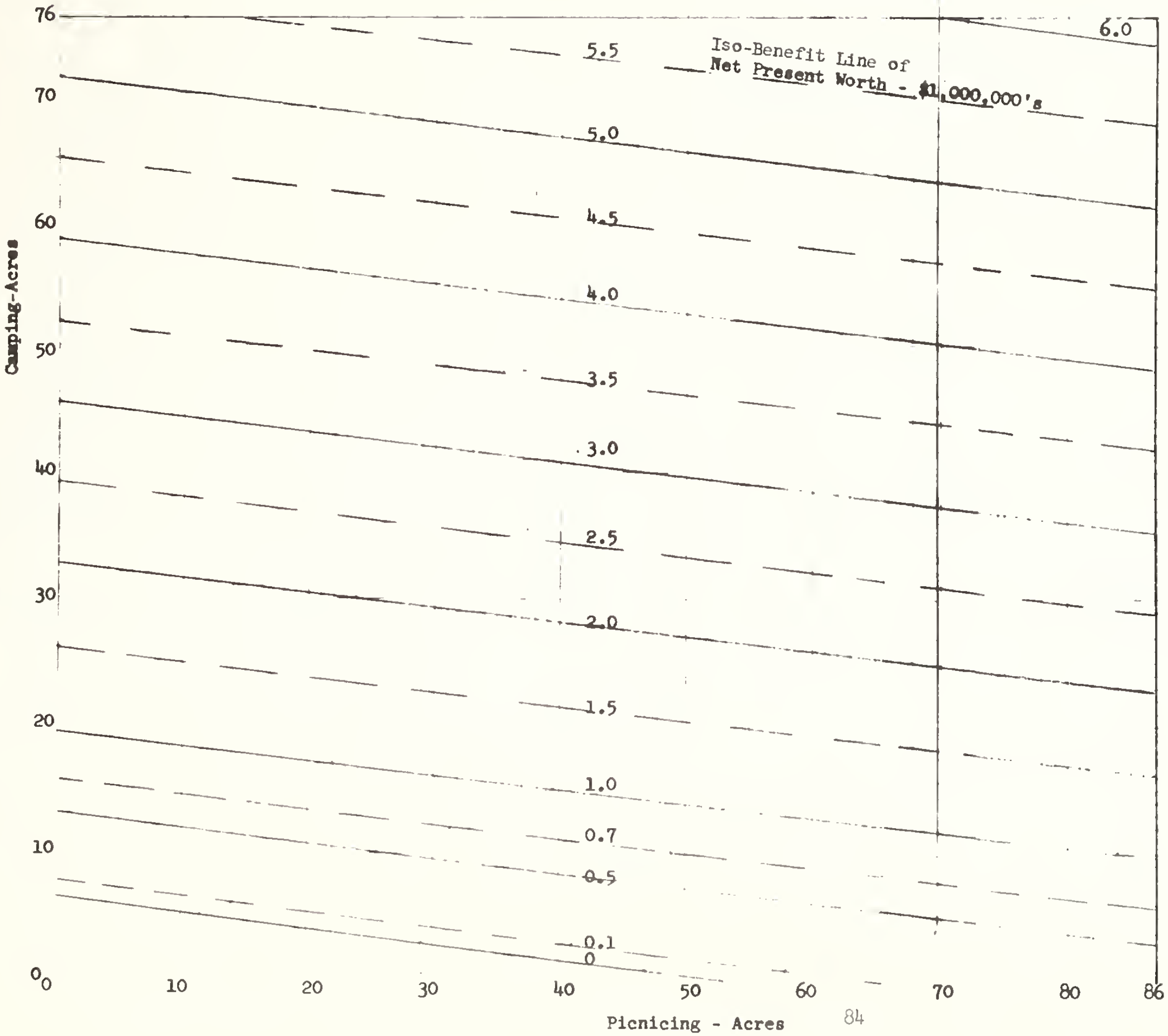


Fig. 9 Iso-product Lines of Dollars Net Present Worth Added to the Patagonia Area by the Proposed Red Rock Dam Recreation Complex - at Various Scales of Camping and Picnicing.

RECOMMENDED ALTERNATIVE - With and Without Project Comparison-Optimization Stage

Includes:

Access Road (3) Harshaw Ck
2 Std. Boat Ramps
Net Change in Onsite Benefits
Downstream Opportunity Costs

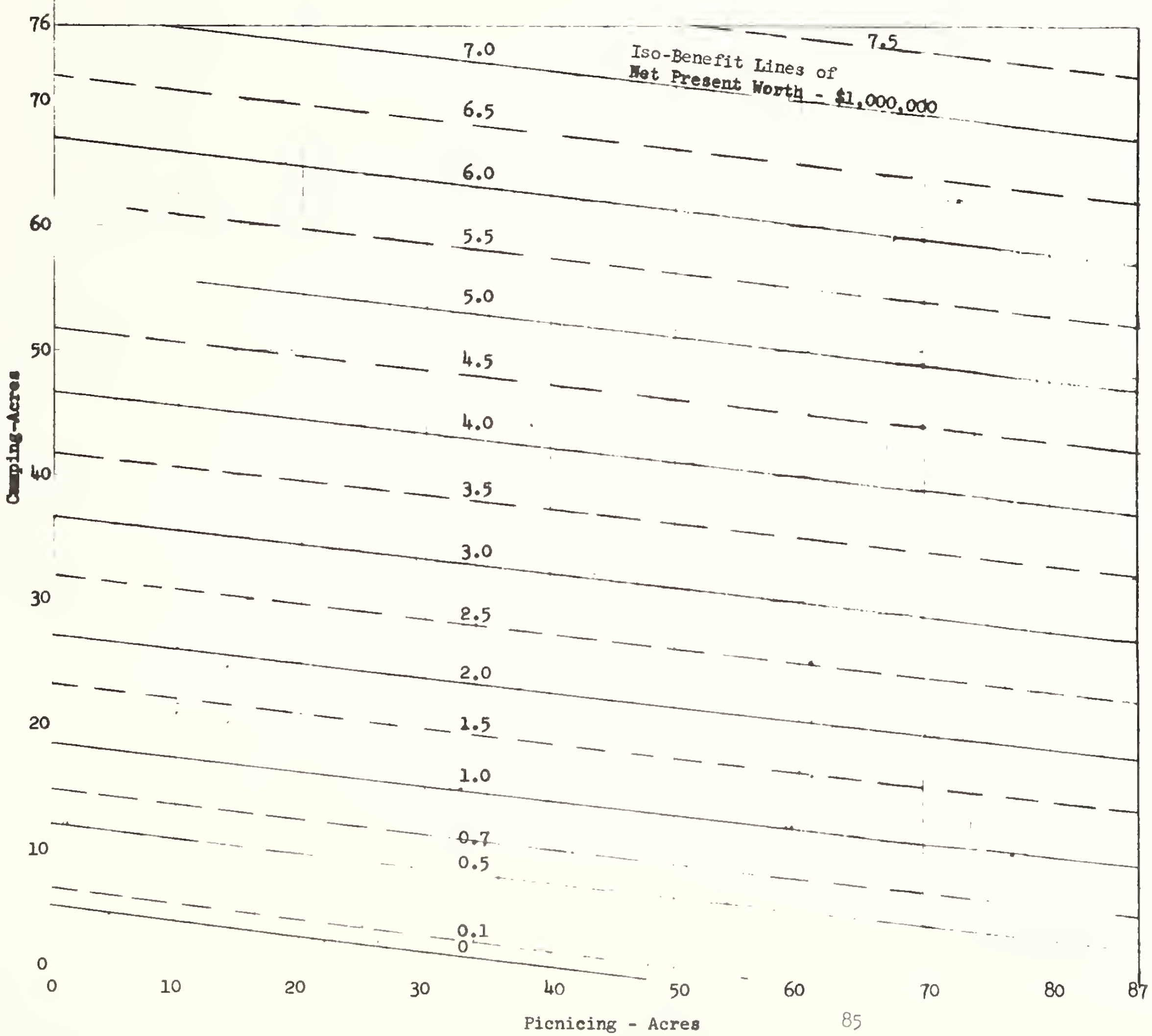


Fig. 10 Iso-product Lines of Dollars Net Present Worth Added to the Patagonia Area by the Proposed Red Rock Dam Recreation Complex at Various Scales of Camping and Picnicing.

ALTERNATIVE - With and Without Project Comparison-Optimization Stage

Includes:

- Access Road (1)
- 1 Econ. Ramp
- Net Change in Onsite Benefits
- Downstream Opportunity Costs

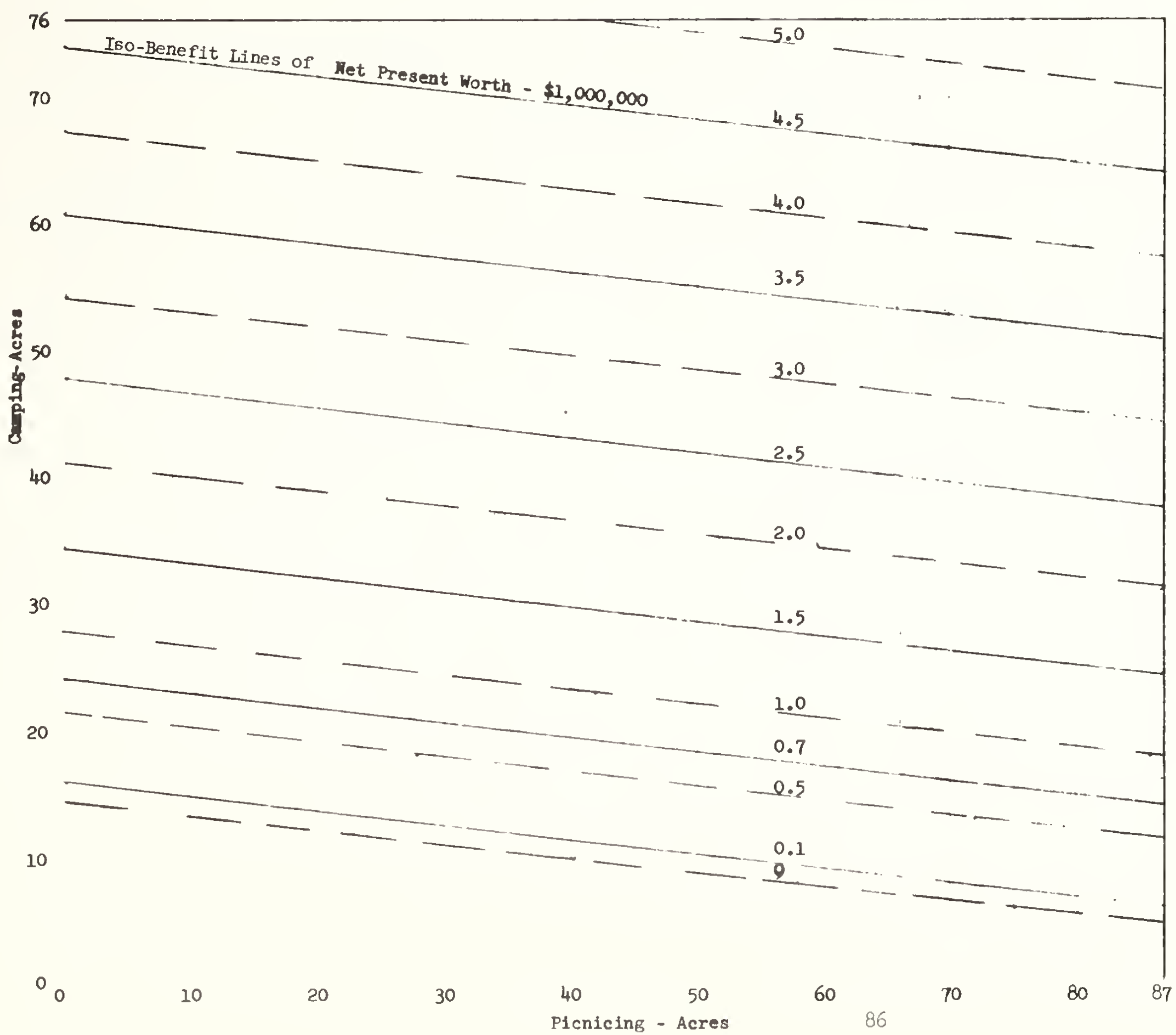


Fig. 11 Iso-product Lines of Dollars Net Present Worth Added to the Patagonia Area by the Proposed Red Rock Dam Recreation Complex at Various Scales of Camping and Picnicing.

ALTERNATIVE - With and Without Project Comparison-Optimization Stage

Includes:

Access Road (2)

1 Econ. Ramp.

Net Change in Onsite Benefits

Downstream Opportunity Costs

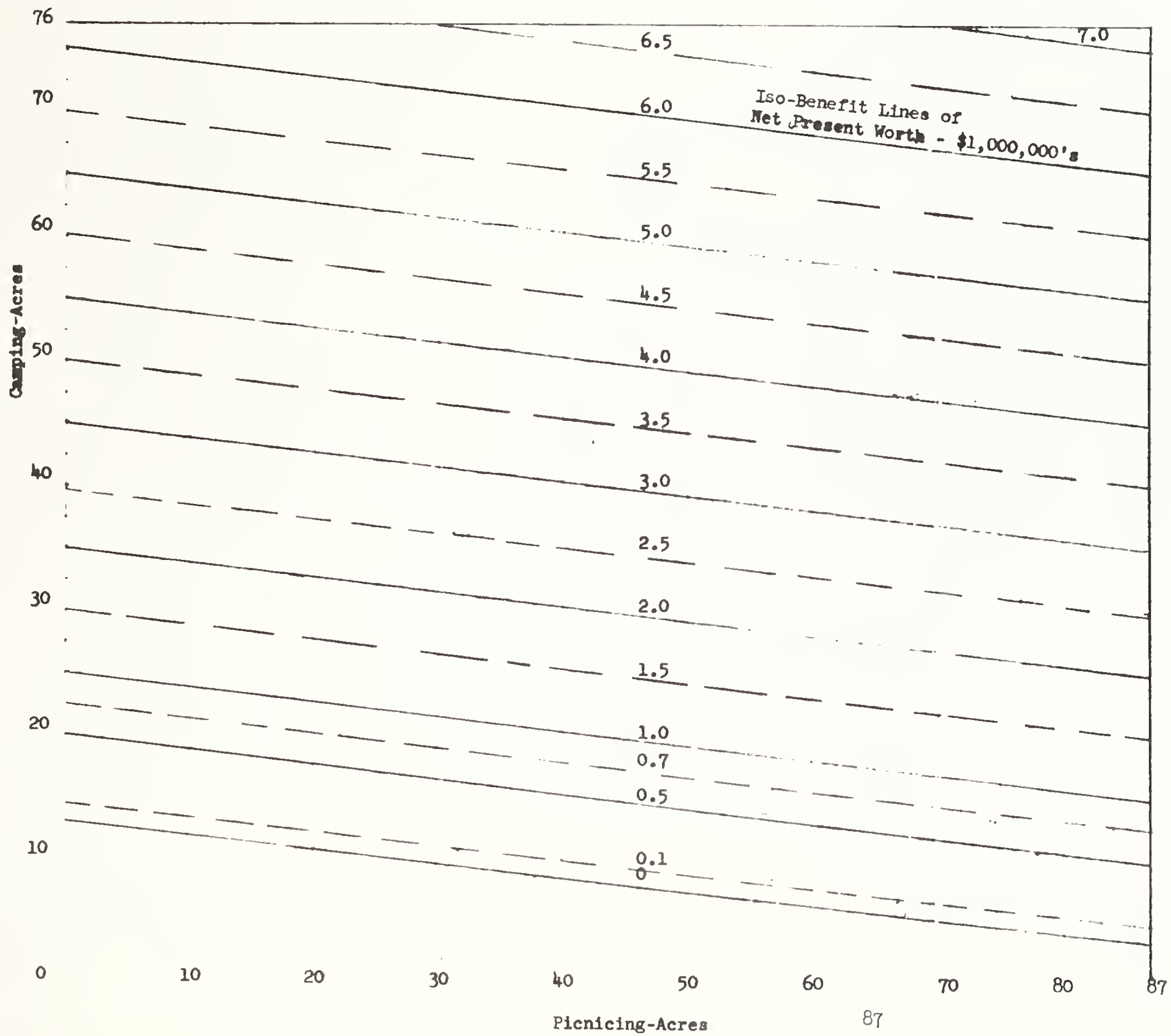
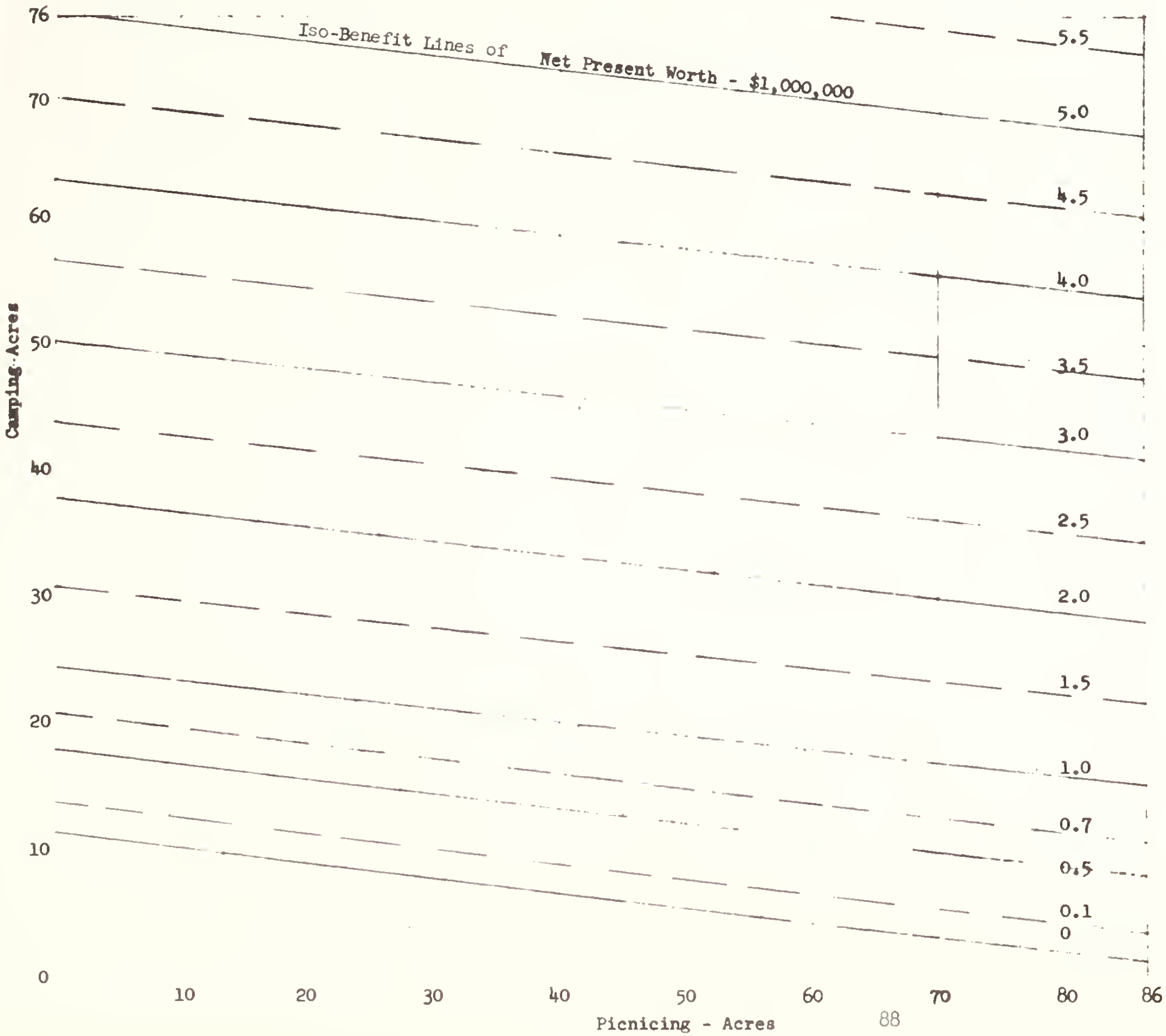


Fig. 12 Iso-product Lines of Dollars Net Present Worth Added to the Patagonia Area by the Proposed Red Rock Dam Recreation Complex at Various Scales of Camping and Picnicing.

ALTERNATIVE - With and Without Project Comparison-Optimization Stage
Includes:
Access Road (3)
1 Econ. Ramp
Net Change in Onsite Benefits
Downstream Opportunity Costs



Part 4. Economic Benefits from Type Conversion to Augument Downstream Water Needs.

Vegetative type conversion alternatives for converting brush and mixed tree and brush areas to grass were alanysed to determine the potential to augment downstream water needs, that dam spilling and reservoir leakage might not always meet. Type conversion could also provide water for other developing needs downstream. Based on their hydrologic characterisitics, four areas were analysed. These were (2) Temporal Gulch, (3) Big Casa Blanca Canyon, (4) Alum Gulch and (5) Harshaw Creek. Big Casa Blanca and Harshaw enter Sonoita Creek above Patagonia and would augument flows through the Nature Conservacy Patagonia-Sonoita Creek Bird Sanctuary. A discussion of the values involved with each downstream use of water is given in Section A.

A linear program analysis was run by the Forest Service Watershed Systems Analysis Unit at Berkeley, California. Several runs were made to find optimal solutions to produce various amounts of new water. The values of water and other benefits, the technical coefficients used and the costs involved are given in Section A, Part 2, Tables 8 and 9. Each area could be converted by spraying or burning and spraying. Costs varied on each area due to conversion methods and road construction needed for access to the areas.

The linear program was run with three different objective functions: (1) Maximize net present worth of benefits, (2) Maximize present worth of benefits, and (3) Minimize present worth of costs. The results are plotted on Figure 13. There is little difference between (1) and (2) in this case.

If management objectives are singular and fixed, then evaluation criteria should evolve around minimizing costs. Where there are multiple outputs and varying intensities, evaluation criteria evolving around maximizing net benefits are better suited for most resource management situations (8) and (9).

The acre feet of new water yield and the net present worth of benefits associated with the yield can be read graphically from Figure 13. The initial costs associated with these yields are plotted on Figure 14. Benefits, costs, and comparisons of net benefits under the three alternative objective functions are shown in Tables 14 through 18. The acres of hydrologic response area treated, and the treatment under each alternative objective function is shown in tables 19, 20, and 21. The optional L-P solution under maximizing net present worth, table 19, is the treatment recommended.

As shown in Figure 13, all new water developed has a positive net present worth. The low net worth for the amount invested is due to relatively low increased water yield potentials on the hydrologic response areas. Fire benefits from reduced fire suppression and area burned account for over 20% of benefits on all areas. An acreage of 87.5 acre feet per year of new water can be developed above Patagonia to supplement downstream water needs not met by spilling and reservoir leakage from the proposed Red Rock Dam. The potential of this water to raise the average flows through the Patagonia-Sonoita Creek Bird Sanctuary during the critical low flow months could be significant to maintaining the socio-economic values of these downstream areas.

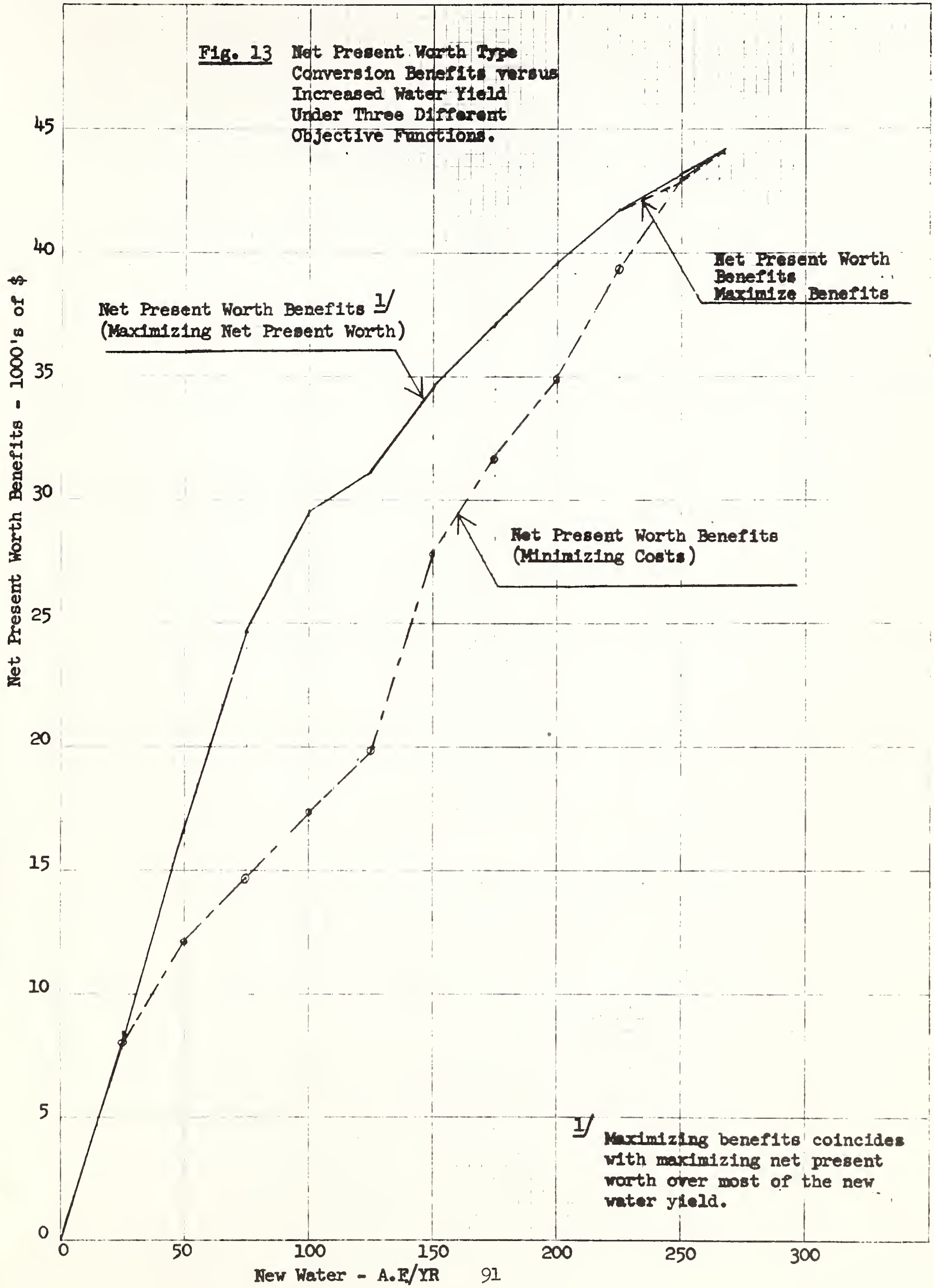


Fig. 13 Net Present Worth Type Conversion Benefits versus Increased Water Yield Under Three Different Objective Functions.
Net Present Worth Benefits 1/ (Maximizing Net Present Worth)
Net Present Worth Benefits Maximize Benefits
Net Present Worth Benefits (Minimizing Costs)
1/ Maximizing benefits coincides with maximizing net present worth over most of the new water yield.
Net Present Worth Benefits - 1000's of $
New Water - A.F/YR
0
5
10
15
20
25
30
35
40
45
50
100
150
200
250
300

Fig. 14 Type Conversion Initial Investment Costs versus Acre Feet New Water

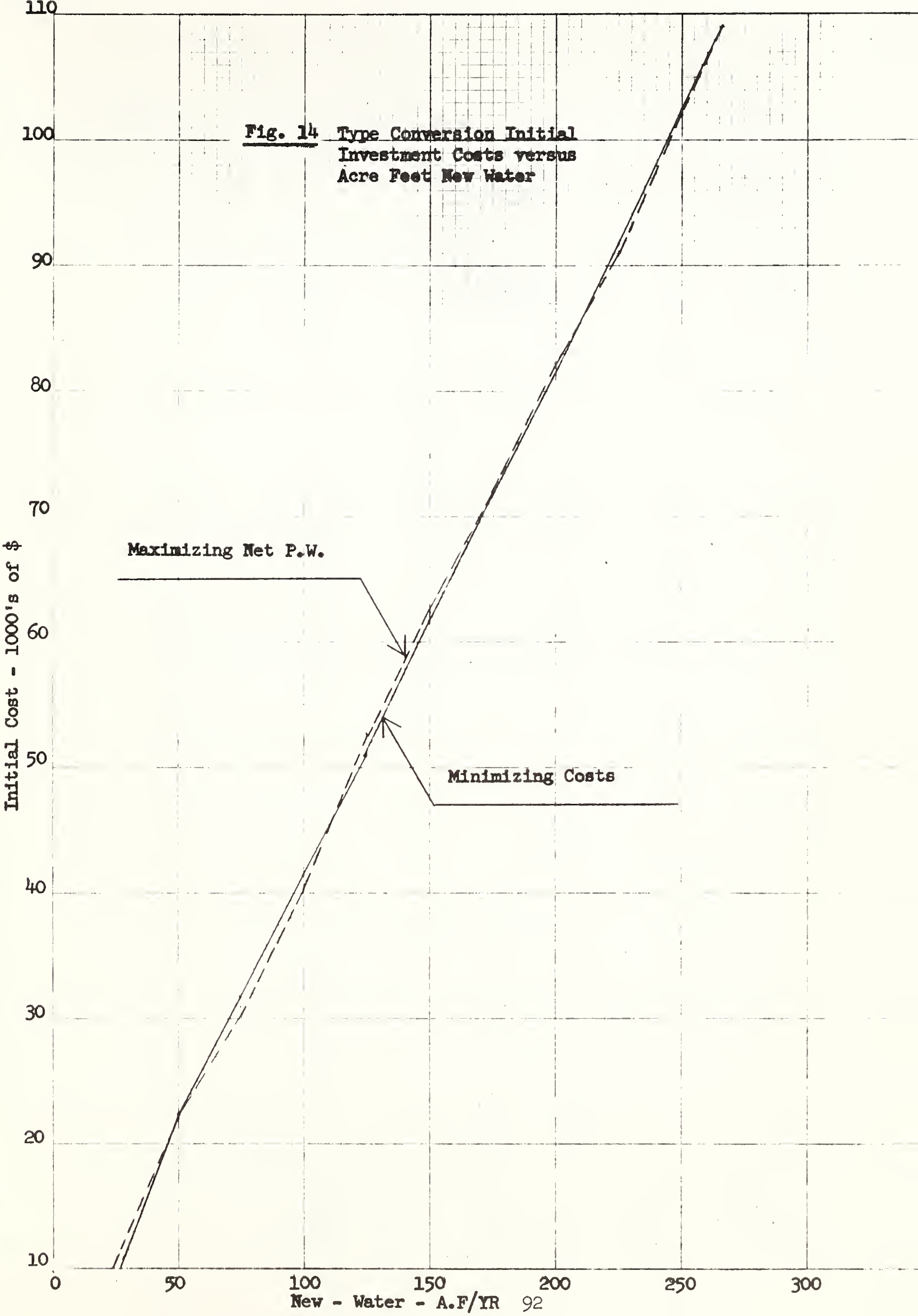


Table 14 Present Worth of Type Conversion Benefits and Costs - $/AC[1]

Commodity	P.W. Benefits- $/AC.	P.W. Costs- $/AC TRT. (1)	P.W. Costs- $/AC TRT. (2)
Water			
H.R. Area			
2	35.29	46.43	50.44
3	53.94	47.45	49.53
4	35.29	45.57	49.30
5	51.16	45.70	48.57
Fire			
H.R. Area			
2	20.60	-	-
3	20.60	-	-
4	20.60	-	-
5	20.60	-	-
Hunting			
H.R. Area			
2	0.12	-	-
3	0.12	-	-
4	0.12	-	-
5	0.12	-	-

1/ See table 9 in Appendix IX.

Table 15 Net Present Worth of Type Conversion Benefits Using Three Different Objective Functions

Total New Water -A.F./Yr.	Minimize Costs		Maximize Costs		Maximize Net P.W. Benefits	
	Net. P.W. -$	Water above Patagonia -AF/Yr.	Net. P.W. -$	Water above Patagonia -AF/Yr.	Net. P.W. -$	Water above Patagonia -AF/Yr.
25	8049	25	8454	25	8454	25
50	12149	32	16540	50	16643	50
75	14718	32	24589	75	24606	75
100	17289	32	29524	87.5	29524	87.5
125	19859	32	32094	87.5	32094	87.5
150	27958	56	34664	87.5	34664	87.5
175	32669	66	37234	87.5	37234	87.5
200	34966	66	39585	87.5	39557	87.5
225	39408	77	41710	87.5	41721	87.5
250	43168	87.5	43036	87.5	43213	87.5
266	44026	87.5	44040	87.5	44076	87.5

Table 16 Type Conversion Initial Treatment Costs - $ and $/AC

Hydrologic Response Area	Roads - $	Costs 1/ Spray & Spray Trt.-1 $/AC	Burn & Spray Trt.-2 $/AC
(2) Temporal Gulch	3000	31.50	34.50
(3) Big Casa Blanca	1000	31.50	34.50
(4) Alum Gulch	500	31.50	34.50
(5) Harshaw	0	31.50	34.50

1/ These are the undiscounted costs for the initial investment period of 3 years, see appendix IV.

Table 17 Distribution of Net Present Worth Benefits from Type Conversion by Commodity - %/Acre 1/

Hydrologic Response Area	Commodity: Fire	New Water	Hunting 2/
2	36	64	Neg.
3	28	72	Neg.
4	36	64	Neg.
5	29	71	Neg.

1/ These percentages represent the change in net benefits on a with and without the project evaluation.

2/ The effect of type conversion on these areas in improving habitat and hunters success is expected to be relatively small. Existing hunter access is generally good.

Table 18 Initial Investment Costs of Type Conversion for Various Scales of Water Yield Increase

- Total $

New Water[1/] -A.F.	Acres Treated	Initial Costs[2/] Maximizing[3/] Net P.W. Benefits-$	Minimizing P.W. Costs-$
25	305	10,608	9,607
50	610	20,215	22,215
75	915	30,168	31,823
100	1,219	40,271	41,398
125	1,524	52,883	51,006
150	1,829	62,490	61,613
175	2,134	72,097	71,756
200	2,439	82,205	81,364
225	2,744	91,924	91,883
250	3,049	102,343	102,405
266	3,243	109,139	109,098

1/ Acre feet increments of new water and acres treated are the same under both methods of analysis because yield per acre treated is about the same on the four hydrologic response areas.

2/ These are the undiscounted costs for the initial investment period of 3 years.

3/ Maximizing net present worth benefits is the objective recommended for this phase of the Red Rock Dam Complex.

Table 19. Optimal Solutions on Areas to Treat for Various Yields of New Water Based on the Objective Function of Maximizing Net Present Worth Benefits 1/

Hydrologic Response Areas 2/

New Water -A.F./Yr.	Treatment - Spray & Spray 1 (2)	(3)	(4)	(5)	Treatment - Burn & Spray 2 (2)	(3)	(4)	(5)	P.W. Cost-$	P.W. Benefits-$	Net P.W.-$
25		305		200					14,466	22,921	8,454
50		410		200					28,583	45,226	16,643
75 3/		410		390		115			42,955	67,561	24,606
100	153	410		390		137		130	57,458	86,982	29,524
125	457	410		390		137		130	71,614	103,370	32,094
150	762	410		390		137		130	85,769	120,400	34,664
175	1,067	410		390		137		130	99,925	137,200	37,234
200	1,151	410	221	390		137		130	114,300	153,900	39,557
225	1,151	410	489	390		137	37	130	128,900	170,600	41,721
250	1,151	410	489	390	178	137	164	130	144,100	187,300	43,213
266	1,151	410	489	390	372	137	164	130	154,000	198,000	44,076

1/ Small acreages may need to be dropped or rounded off in actual field application.

2/ Hydrologic response areas 3 and 5 are above the Patagonia-Sonoita Creek Bird Sanctuary.

3/ If only area 3 and 5 are treated at this scale then the maximum new water yield for areas above Patagonia has been reached at 87.5 acre feet or 1,067 acres treated.

Table 20. Optimal Solutions on Areas to Treat for Various Yields of New Water Based on the Objective Function of Maximizing Net Present Worth Benefits 1/

Hydrologic Response Areas 2/

New Water -A.F./Yr	Treatment - Spray & Spray (2)	(3)	(4)	(5)	Treatment - Burn & Spray (2)	(3)	(4)	(5)	P.W. Cost-$	P.W. Benefits-$	Net P.W.-$
25		305							14,466	22,920	8,454
50		410		63		137			29,108	45,648	16,643
75		410		368		137			43,041	67,630	24,606
100	153	410		390		137		130	57,458	86,982	29,524
125	457	410		390		137		130	71,614	103,708	32,094
150	762	410		390		137		130	85,769	120,433	34,664
175	1,067	410		390		137		130	99,925	137,159	37,234
200	1,151	410	221	390		137		130	114,300	153,885	39,557
225	1,151	410	489	390	36	137		130	128,900	170,610	41,721
250	1,151	410	489	390	342	137		130	144,300	187,336	43,213
266	1,151	410	489	390	384	137	153	130	154,000	198,040	44,076

1/ Small acreages may need to be dropped or rounded off in actual field application.

2/ Hydrologic response areas 3 and 5 are above the Patagonia-Sonoita Creek Bird Sanctuary.

Table 21. Optimal Solutions on Areas to Treat for Various Yields of New Water Based on the Objective Function of Minimizing Costs 1/

Hydrologic Response Areas 2/

New Water -A.F./YR	Treatment - Spray & Spray (2)	(3)	(4)	(5)	Treatment - Burn & Spray (2)	(3)	(4)	(5)	P.W. Cost -$	P.W. Benefits-$	Net P.W. - $
25				305					13,993	21,982	8,049
50	220			390					28,026	40,175	12,149
75	525			390					42,182	56,900	14,718
100	829			390					56,337	73,626	17,289
125	1,134			390					70,493	90,352	19,859
150	1,151	288		390					84,942	112,900	27,958
175	1,151	410	183	390					99,431	132,100	32,669
200	1,151	410	488	390					113,934	148,900	34,966
225	1,151	410	489	390		137	164	3	128,992	168,400	39,408
250	1,151	410	489	390	178	137	164	130	144,132	187,300	43,168
266	1,151	410	489	390	372	137	164	130	153,974	198,000	44,026

1/ Small acreages may need to be dropped or rounded off in actual field application.

2/ Hydrologic response areas 3 and 5 are above the Patagonia - Sonoita Creek Bird Sanctuary.

Part 5. Conclusions

The economic evaluation shows that for any of the alternative combinations of access road and fishing ramps, the proposed Red Rock Dam Complex can have a positive net benefit at the System Level or Optimization Stage - if the scale of development is large enough to cover the opportunity costs (see table 8). Fishing alone could just barely meet all costs if access road (3) and two standard fishing ramps were used. However, additional investment in picnicking and camping can improve the project considerably as shown in figures 4 through 12. The recommended project alternative is the Harshaw Creek - two standard boat ramp combination with picnicking and camping as shown in Figure 9.

As was discussed earlier in part 1, most of the benefits from this type of project will accrue to the National Economic Sectors of Retail Trade - food stores and general merchandise, and Selected Services - gasoline and oil, and service and repair, with some effect on building, housing and employment. Multipliers for these sectors in Southern Arizona are listed in table 14, Section A, Part 4.

Opportunity costs could possibly be lowered as much as $110,000 from spillage and reservoir seepage at the dam. An additional $24,000 could come from type conversion in Harshaw Creek and Big Casa Blanca Canyon. Other downstream water needs could receive augmentation from Alum Canyon and Temporal Gulch.

The effect of the water from dam spillage, reservoir leakage and type conversion on critical low flows through downstream areas could be very significant if it actually increases these flows. If this is the case, then opportunity costs

would be less and social-economic values could increase downstream rather than decrease.

When using the proposed Red Rock Dam alternatives as set up in figures 4 through 12, reference should be made to the series of iso-product or iso-benefit lines of equal net present worth, any combination of picnicking and camping intersecting the iso-product line would produce the same net present worth value. Presented in this way, the resource manager can pick the alternatives to meet the objectives, and within the budgeting constraints, locate the scale of development he could go to, and then determine what it would return in net present worth of benefits. In light of the implications of these data, the resource manager might decide to re-examine the objectives or look at new alternatives. In using diagrams 4 through 12 keep in mind that only one intensity of camping and picnicking was used, with a 45:55 fixed ratio of picnicking to camping, different intensities could generate a whole new series of possible solutions - depending on what the objectives were and what the various constraints on production, acreage, and demand might be.

Part 6 References

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APPENDIX V

HYDROLOGY

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NO. 2

DRAINAGE ANALYSIS AND HYDROLOGIC RESPONSE UNITS

Drainage characteristics of the Red Rock Canyon Watershed were evaluated on a 7-1/2 minute. U.S.G.S. topographic quad, scale 1/62500. Based primarily on the surface geomorphic characteristics, Red Rock Canyon Watershed was divided into eight (8) subwatersheds. The criteria for delineating first order channels are: 1) The channel must exhibit more than 1000 foot change in the general configuration of the contour and 2) the channel must deliver direct to a channel of higher order.

The subwatersheds were the basic hydrologic units in computing floods for spillway design and the simulation study using the watershed model (Water Balance Program, Shumway, 1968). The geomorphic and hydrologic characteristics of the subwatersheds are given below:

Table 1. Drainage Characteristics

Sub-watershed	Area (Acres)	Relief-Length Ratio	Channel Order	No. of Channels	Ave. Length of Order	Ave. Slope of Order
1	1,768	0.083	1	10	2,700	-
			2	3	3,000	5.2
			3	1	3,200	1.94
2	2,635	0.030	1	11	3,036	-
			2	2	4,250	2.33
			3	1	12,800	2.07
3	1,577	0.032	1	5	3,160	-
			2	2	3,800	1.7

Table 1. continued

Sub-watershed	Area (Acres)	Relief-Length Ratio	Channel Order	Number of Channels	Ave. Length of Order	Ave. Slope of Order
			3	1	4,400	2.28
4	3843	0.048	1	16	3,081	-
			2	5	5,880	6.6
			3	1	8,900	2.36
5	618	0.050	1	2	3,800	-
			3	1	6,800	1.1
6	2004	0.053	1	8	4,288	-
			2	1	1,800	5.28
			4	1	9,200	1.16
7	3429	0.061	1	10	5,380	-
			2	2	2,700	4.82
			3	1	11,200	2.27
8	1956	0.014	1	5	4,000	-
			4	1	15,200	2.13

Hydrologic Response Units (HRU) represent areas having similar geomorphic, edaphic and vegetative characteristics which will exhibit a similar hydrologic response to watershed management prescriptions. Red Rock Canyon Watershed was divided into 22 HRU's. Within the treatable areas in the Santa Rita and Patagonia mountains, 4 HRU's were delineated. The HRU's were identified with the following code system:

Precipitation Zone

Sub-watershed 1 A 1 HRU

Tables 2 and 3 give the characteristics of the HRU's for Red Rock Canyon and treatable areas.

Table 2. Hydrologic Response Units for Red Rock Canyon

HRU	Depletable Storage Capacity (in)	Total Storage Capacity (in)	Depletable Moisture 7-1-1935 (in)	Total Moisture 7-1-1935 (in)	Depletion Constant K	Slope %	Aspect	Average Elevation (Ft)	Area (Acres)
1A1	5.40	8.68	0.09	0.87	0.55	50	SW	5600	555
1A2	11.09	11.09	0.55	1.11	0.10	15	SW	5250	95
1A3	8.72	8.72	0.14	0.87	0.15	15	W	5200	1,118
2A1	10.17	11.97	0.51	1.19	0.55	10	W	5050	788
2A2	8.72	8.72	0.14	0.87	0.55	20	W	5000	1,837
3A1	10.17	11.97	0.51	1.97	0.55	5	N	5000	386
3A2	0.05	6.00	0.00	0.60	0.80	20	N	5000	164
3A3	8.72	8.72	0.14	0.87	0.55	27	N	4850	1,013
3A4	4.20	72.0	0.40	7.20	0.75	1	W		14
4A1	5.40	8.68	0.09	0.87	0.55	30	SW	5500	2,327
4A2	11.09	11.09	0.55	0.55	0.10	15	SW	5150	106
4A3	8.72	8.72	0.14	0.87	0.55	30	NW	4900	1,410
5B1	8.72	8.72	0.14	0.87	0.55	17	SW	4650	618
6B1	8.72	8.72	0.14	0.87	0.55	30	W	4800	2,004
7B1	5.40	8.68	0.09	0.09	0.87	50	SW	5600	1,346
7B2	8.70	8.72	0.14	0.87	0.55	35	W	4800	1,379
7B3	8.57	8.57	0.13	0.86	9.10	5	W	4450	574
7B4	0.05	6.00	6.00	0.60	0.80	35	E	4650	130
8B1	4.52	8.72	0.14	0.87	0.55	25	W	4650	893
8B2	7.97	7.97	0.10	0.80	0.55	20	NE	4500	645
8B3	4.40	8.60	0.14	0.87	0.55	50	SE	4400	336
8B4	4.20	72.0	0.40	7.20	0.75	1	W	4450	82
[illegible]	Lake								

Table 3. Hydrologic Response Units for Treatment Areas

	Before Treatment		After Treatment		Before Treatment		After Treatment		Before Treat.	After Treat.				
HRU	Deplet. Stge. Capac. (in)	Total Stge. Capac. (in)	Deplet. Stge. Capac. (in)	Total Stge. Capac. (in)	Deplet. Moist. 7-1-1935 (in)	Total Moist. 7-1-1935 (in)	Deplet. Moist. 7-1-1935 (in)	Total Moist. 7-1-1935 (in)	Deplet. Const. K	Deplet. Const. K	Slope (%)	Aspect	Aver. Elev. (Ft)	Area (Acres)
Drainages above Patagonia and Bird Sanctuary														
Harshaw Creek (Patagonia Mts.)														
A1	7.63	7.63	4.90	7.63	0.25	0.55	0.50	1.10	0.55	0.55	30	345	5200	520
Big Casa Blanca Canyon (Santa Rita Mts.)														
A2	7.03	7.03	4.90	7.03	0.30	0.30	0.60	0.60	0.45	0.45	30	10	5800	547
													Sub-total	1,067
Drainages below Bird Sanctuary and Above Lake Patagonia														
Alum and Three R Canyon (Patagonia Mts.)														
A3	7.63	7.63	4.90	7.63	0.25	0.55	0.50	1.10	0.55	0.45	30	345	5500	622
Temporal Gulch														
A4	7.03	7.03	4.90	7.03	0.30	0.30	0.60	0.60	0.45	0.45	35	10	5700	1535
													Sub-total	2,157
													TOTAL	3,224

RED ROCK CANYON SURVEY

SUMMARY WATER BALANCE FOR SUBUNITS 7R1 THRU 8R3

COMPUTED 03/23/ USING THORNTAITE METHOD FOR PE COMPUTATIONS

Exhibit 3

DATA STARTS ON 1/ 1/45 AND CONTINUES FOR 23 YEARS

REGION 3 HYDROLOGIC PROVINCE 2 SUBPROVINCE 14 4410.0 ACRES

WATER BALANCE BEFORE TREATMENT

MONTH	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL	AC.FT.
TOTAL PRECIP.	0.94	0.18	1.48	0.10	0.00	0.00	3.65	5.26	0.88	2.26	0.00	0.17	14.92	
COMPUTED PE	0.46	0.68	0.94	1.64	2.94	3.74	5.29	4.59	3.56	2.61	1.25	0.57	28.26	
NET PE	0.45	0.66	0.92	1.59	0.93	0.01	3.39	4.40	1.28	2.09	0.02	0.13	15.87	
ACCUM. SNOW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
DEFICIT	0.01	0.02	0.02	0.05	2.00	3.73	1.91	0.19	2.28	0.52	1.23	0.44	12.39	
STORAGE	3.13	2.56	2.95	1.40	0.45	0.44	0.48	0.99	0.50	0.51	0.48	0.47		
EXCESS	0.08	0.05	0.09	0.03	0.01	0.01	0.10	0.16	0.03	0.07	0.01	0.01	0.65	73.38

ALL TABLE ENTRIES ARE IN INCHES

RED ROCK CANYON SURVEY

COMPUTED 03/23/ USING THORNTHWAITE METHOD FOR PE COMPUTATIONS

DATA STARTS ON 1/ 1/45 AND CONTINUES FOR 23 YEARS

Exhibit 4

REGION 3 HYDROLOGIC PROVINCE 2 SUBPROVINCE 14 MAP UNIT 7R5 1.0 ACRES

WATER BALANCE BEFORE TREATMENT

MONTH	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL	AC.FT.
TOTAL PRECIP.	0.94	0.18	1.48	0.10	0.00	0.00	3.65	5.26	0.88	2.26	0.00	0.17	14.92	
COMPUTED PE	1.70	2.61	4.39	5.53	7.27	5.93	6.19	2.83	2.52	2.72	1.18	1.71	44.57	
NET PE	1.70	2.61	4.39	5.53	7.27	5.93	6.19	2.83	2.52	2.72	1.18	1.71	44.57	Lake Evaporation
ACCUM. SNOW	.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
DEFICIT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
STORAGE	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00		
EXCESS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.43	0.00	0.00	0.00	0.00	2.43	0.20

ALL TABLE ENTRIES ARE IN INCHES

RED ROCK CANYON TREATABLE AREAS

SUMMARY WATER BALANCE FOR SUBUNITS A1 THRU A4

Exhibit 5

COMPUTED 03/19/ USING THORNTAITE METHOD FOR PE COMPUTATIONS

DATA STARTS ON 1/ 1/45 AND CONTINUES FOR 23 YEARS

REGION 3 HYDROLOGIC PROVINCE 2 SUBPROVINCE 14 3224.0 ACRES

WATER BALANCE BEFORE TREATMENT

MONTH	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL	AC.FT.
TOTAL PRECIP.	1.10	0.32	1.32	0.28	0.00	0.00	3.54	5.97	1.02	2.30	0.00	0.15	16.00	
COMPUTED PE	0.21	0.40	0.66	1.33	2.57	3.37	4.67	3.86	2.74	1.78	0.71	0.26	22.56	
NET PE	0.21	0.40	0.66	1.33	1.47	0.00	3.24	3.86	2.46	1.78	0.29	0.06	15.76	
ACCUM. SNOW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
DEFICIT	0.00	0.00	0.00	0.00	1.10	3.37	1.43	0.00	0.29	0.00	0.42	0.20	6.80	
STORAGE	2.65	2.34	2.69	1.47	0.00	0.00	0.00	1.58	0.00	0.29	0.00	0.00		
EXCESS	0.14	0.13	0.15	0.08	0.00	0.00	0.00	0.09	0.00	0.02	0.00	0.00	0.60	25.80

WATER BALANCE AFTER TREATMENT 3224.0 ACRES

MONTH	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL	AC.FT.
TOTAL PRECIP.	1.10	0.32	1.32	0.28	0.00	0.00	3.54	5.97	1.02	2.30	0.00	0.15	16.00	
COMPUTED PE	0.21	0.40	0.66	1.33	2.57	3.37	4.67	3.86	2.74	1.78	0.71	0.26	22.56	
NET PE	0.21	0.40	0.66	1.33	1.87	0.00	3.41	3.86	1.94	1.78	0.40	0.11	15.98	
ACCUM. SNOW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
DEFICIT	0.00	0.00	0.00	0.00	0.70	3.37	1.26	0.00	0.80	0.00	0.31	0.15	6.59	
STORAGE	3.39	3.10	3.50	2.29	0.40	0.38	0.36	2.16	1.11	1.46	1.00	0.95		
EXCESS	0.18	0.17	0.19	0.12	0.02	0.02	0.02	0.12	0.06	0.08	0.05	0.05	1.09	47.12
WATER INCREASE	0.04	0.04	0.04	0.04	0.02	0.02	0.02	0.03	0.06	0.06	0.05	0.05	0.49	21.32

ALL TABLE ENTRIES ARE IN INCHES

NO. 3

WATERSHED SIMULATION

MODEL

Using thirty-two years of hydrometeorological records; monthly streamflow from the Red Rock Canyon Watershed and the potentially treatable areas in the Santa Rita and Patagonia Mountains was simulated to determine what effect construction of a dam at Site "A" would have on the flow regime downstream. Of specific concern were the effects of the above activities on the Patagonia Bird Sanctuary and Lake Patagonia.

The Watershed model is essentially a mathematical reproduction of the hydrologic processes within the hydrologic cycle. Given below is a brief description of the watershed model inputs used in this report:

A. Precipitation

U. S. Weather Bureau climatological records were analyzed from 1935 to 1967 and monthly precipitation extracted. Using the Theissen Polygon method, precipitation within the Red Rock Watershed was weighted between the Patagonia and Canelo Stations. An analysis of the 32 years of record indicated no significant difference in yearly precipitation resulting from elevation differences between the two gages. Missing data was prorated from surrounding stations.

B. Temperature

Analysis of mean annual temperature from 1935 to 1967 for the Canelo (elev. 4985 ft.), San Rafael (elev. 4741 ft.) and Nogales (elev. 3800 ft.) stations indicated a lapse rate of 3.9°F per 1000 foot change in elevation. Because of its close proximity to the Red Rock Watershed,

mean monthly temperature from the Canelo station was used as a base. Elevation adjustments in temperature for each hydrologic response unit (HRU) were determined from the following equation:

$$T_u = T_B - \left[(0.00391\ E_u) - 19.55\right]$$

Where:

T_u = mean monthly temperature (°F) of an HRU

T_B = mean monthly temperature (°F) of base station (in this case, Canelo)

E_u = mean elevation (ft.) of HRU

Missing data were prorated from surrounding stations.

C. Potential Evapotranspiration

The Thornthwaite Equation given below, was used to predict potential evapotranspiration (PE):

$$PE = 1.6\ (10T/I)^a\ c\ D$$

Where:

I = Heat Index, or $\sum_{i=1}^{12} \left(\frac{T_i}{5}\right)^{1.514}$

T_i = mean monthly temperature (°C)

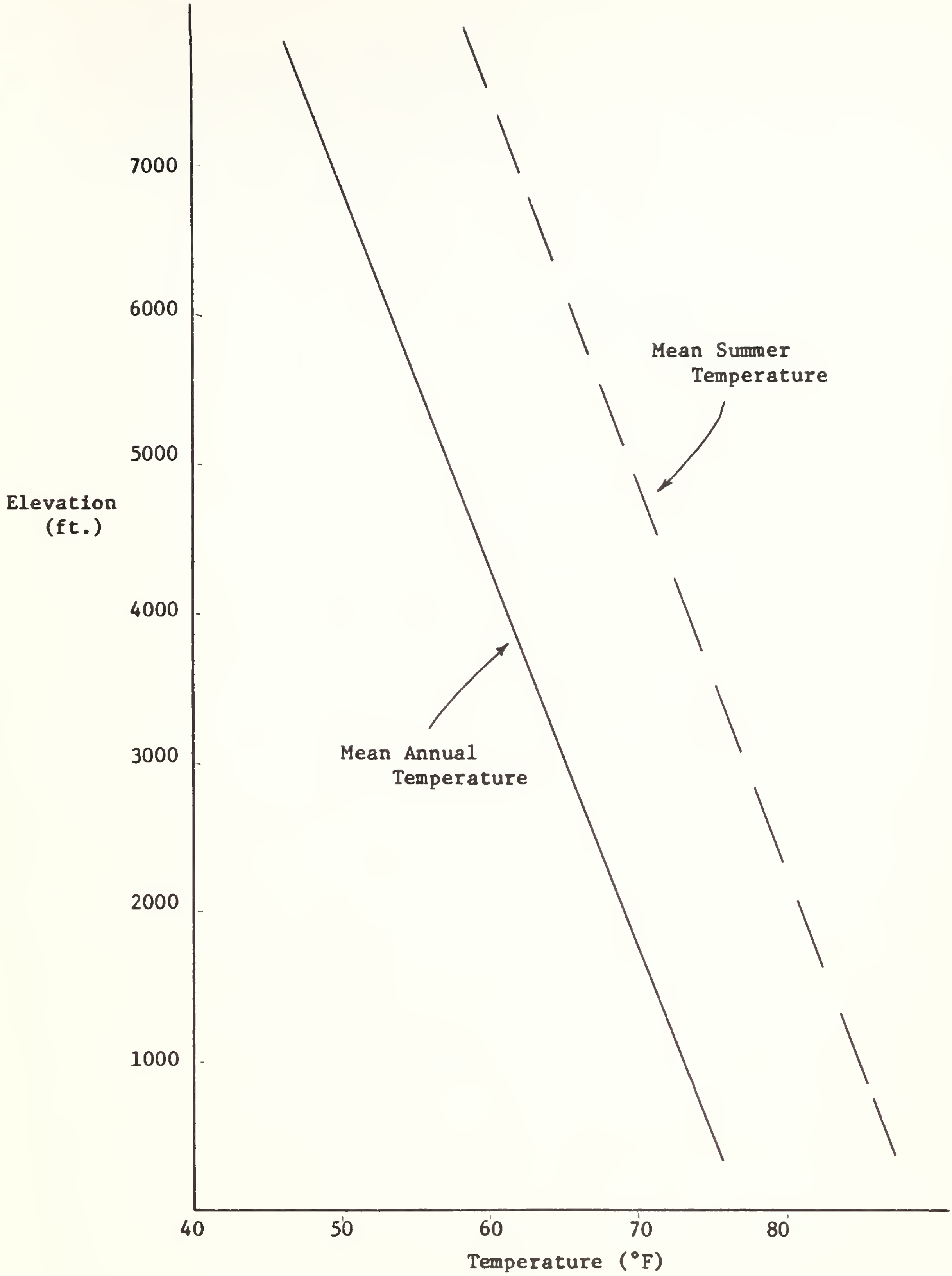
$a = 6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 1.792 \times 10^{-2} I + 0.49239$

T = mean temperature for the observation period

PE = estimated potential evapotranspiration for given period (inches)

c = conversion factor to convert PE from cm/30 day month to inches per observation period.

D = day length in units of 12 hours.



Elevation - Temperature Relationships
Red Rock Canyon

Figure 1

D. PE adjustment for slope-aspect

Because of varying energy relations on different aspects and slopes, a slope-aspect correction factor was used to adjust PE. The correction factor is in the form of a ratio between solar radiation on an inclined surface to solar radiation on a horizontal surface.

$$\frac{Q_i}{Q} = \cos i + \tan Z \sin i \cos \alpha'$$

Where:

$\frac{Q_i}{Q}$ = ratio

i = slope angle of surface

Z = solar zenith angle

α = azimuth of sun from south at noon (or $\alpha = 0$)

While radiation itself is not used in the Thornthwaite Method, it was concluded that the above ratio could be used as an index of PE differences on differing slopes and aspects.

E. Lake Evaporation

The Lake Hefner Lake Evaporation Equation was used to predict lake evaporation from the simulated Red Rock Reservoir.

$$E = 0.0065 \, (e_s - e_a) \, U$$

Where:

e_s = Vapor Pressure at water surface temperature (in Hg)

e_a = Vapor Pressure of over running air (in. Hg)

U = Wind speed (mph)

E = Lake Evaporation (in/day)

Monthly Relative Humidity (RH) was computed to determine vapor pressure. From an analysis of the Nogales and San Rafael Ranch Relative Humidity Records, it was found that mean monthly RH could be predicted from the following equation:

$$RH_{(\%)} = 16.547 \left[\log \left(\frac{P}{T} (1000) \right) \right] + 29.554$$

Where:

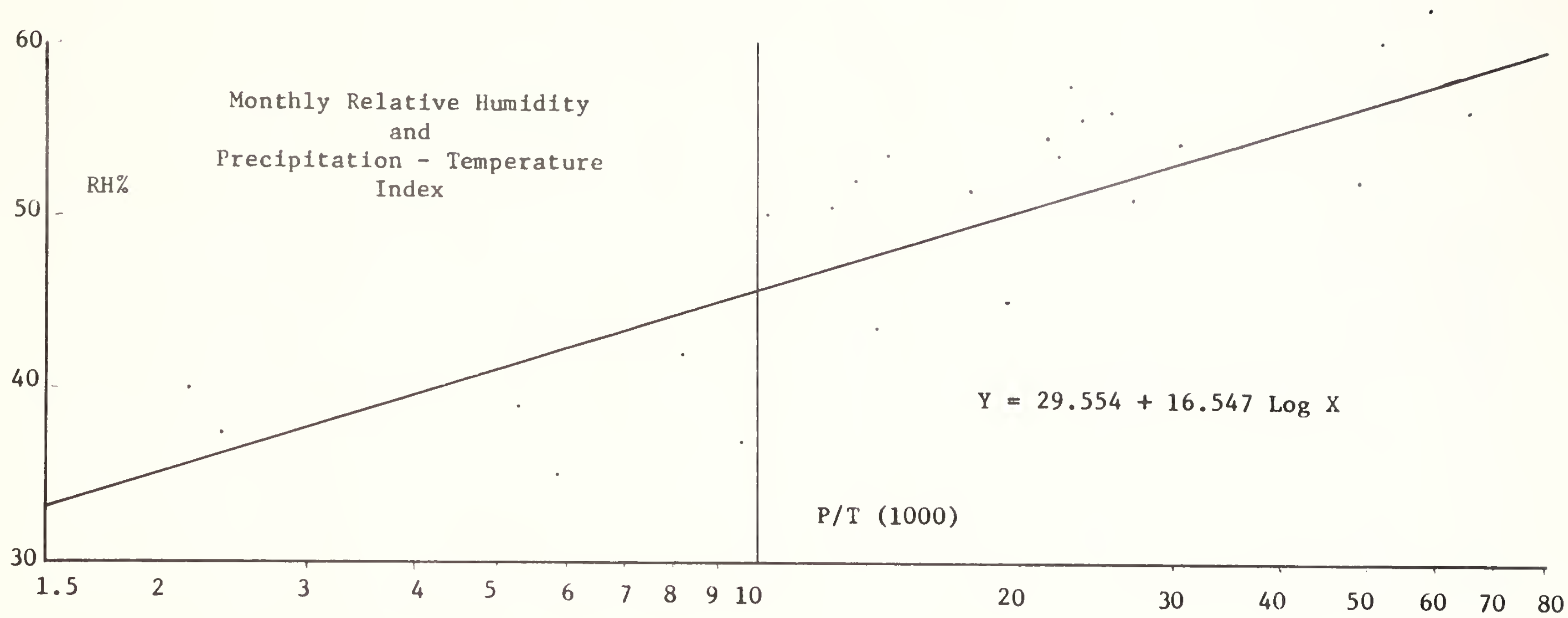
$\frac{P}{T}$ = Index: Ratio of monthly precipitation to mean monthly temperature.

Wind speed was taken from the Nogales station from 1952 to 1967. A comparison of these monthly records with those of Tucson indicated a consistent ratio of monthly wind speeds between the two stations (Table 1). Prior to 1952, the Tucson wind data was used with the corresponding monthly ratio to predict wind movement at Nogales.

Table 1. Monthly Wind Ratios - Nogales-Tucson

	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Ratio	2.06	2.23	2.33	2.03	1.93	1.80	1.24	0.925	1.00	1.51	1.57	1.94

Water surface temperatures of the simulated lakes were estimated using relationships observed in the Lake Mead and Lake Hefner studies. Analysis of monthly ambient and water surface air temperatures indicated that monthly ratios of the two could consistently describe both the amplitude and magnitude of the lag between ambient and water surface air temperatures for the simulated lake.



Monthly Relative Humidity
and
Precipitation - Temperature
Index
RH%
60
50
40
30
1.5
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
P/T (1000)
Y = 29.554 + 16.547 Log X

Figure 2

Table 2. Monthly Temperature Ratios - $\frac{\text{Temperature of Ambient Air}}{\text{Temperature of Air at Water Surface}}$

	J	F	M	A	M	J	J	A	S	O	N	D
Ratio	0.828	0.907	0.929	0.962	1.010	1.052	1.074	1.069	1.059	0.986	0.928	0.832

The surface area of the lake at any storage was computed from the following equations developed from the area-capacity curves from the reservoir.

Reservoir "A"

Below 1000 AF Storage: $A_s = 0.05\ S_T$

Above 1000 AF Storage: $A_s = 0.029\ S_T + 20.4$

Where: S_T = Storage in AF

A_s = Surface area of Lake in Acres

F. Interception

Interception loss by plants was computed with the following equation:

$$I = B_i + PR_r$$

Where:

I = Interception in inches

B_i = Base amount

P = Precipitation

R_r = Interception Rate

Both B_i and R_r were varied by season to allow for variations in seasonal differences in storm intensity and duration and nature of the plant cover.

Table 3. Interception Coefficients

Months	B_i	R_r
June-October	0.074	0.032
November-May	0.037	0.026

REDROCK LAKESITE "A"

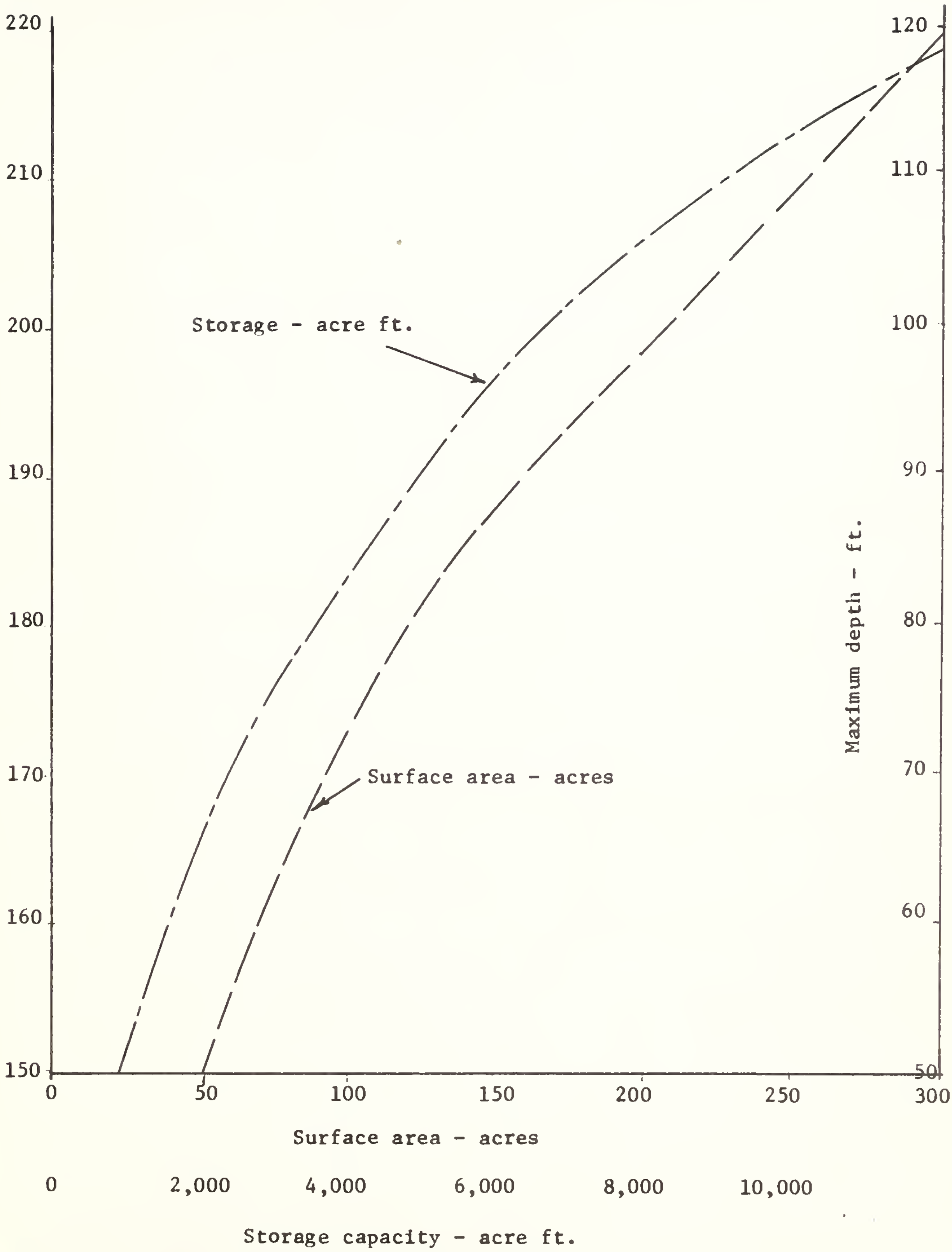


Figure 3

G. Soil Moisture Depletion

The soil moisture depletion function given below describes the soil moisture release characteristics in response to evapotranspiration. The depletion constant K is dependent on the physical characteristics of the soil and the amount of soil moisture in storage.

$$SM_d = SM_o\left(1 - e^{-kt}\right)$$

Where:

SM_d = Amount of soil moisture depleted in inches of water

SM_o = Soil moisture supply at start of the observation period

e = Base of natural logarithms

k = Depletion constant

t = Number of days in the observation period

The depletion constants K for each HMU are discussed in the Soils Appendix.

H. Ground Water Depletion or Base Flow

The ground water depletion function dewcribes the release characteristics of a watershed with a certain amount of water in storage.

$$Q_t = -S_t\left(\ln K_r\right)$$

Where:

Q_t = Base flow in inches at time

S_t = Available storage at time t in inches

$\ln K_r$ = $\log_e$ of the recession constant K_r

Three hundred twenty-seven daily recession flows over a four year period at the Sonoita Creek gage were analyzed. By holding the watershed characteristics constant, hydrograph recession characteristics are related to the nature of the precipitation falling on the watershed. The monthly recession constant was predicted using the following equation:

EXHIBIT 1

1/ 1	0.00890	-4.72202		
1/ 1	0.00801	-4.82738	0.900	0.105
1/ 2	0.00623	-5.07870	0.778	0.251
1/ 3	0.00534	-5.23285	0.857	0.154
1/ 4	0.00480	-5.33821	0.900	0.105
1/ 5	0.00445	-5.41517	0.926	0.077
1/ 6	0.00391	-5.54300	0.880	0.128
1/ 7	0.00356	-5.63832	0.909	0.095
1/ 9	0.00356	-5.63832		
1/ 9	0.00285	-5.86146	0.800	0.223
1/10	0.00267	-5.92600	0.938	0.065
1/11	0.00249	-5.99499	0.933	0.069
1/12	0.00231	-6.06910	0.929	0.074
1/13	0.00214	-6.14914	0.923	0.080
1/14	0.00196	-6.23615	0.917	0.087
1/15	0.00178	-6.33146	0.909	0.095
1/20	0.01068	-4.53970		
1/20	0.00890	-4.72202	0.833	0.182
1/21	0.00730	-4.92048	0.820	0.198
1/22	0.00623	-5.07870	0.854	0.158
1/23	0.00463	-5.37595	0.743	0.297
1/24	0.00391	-5.54300	0.846	0.167
1/25	0.00303	-5.80083	0.773	0.258
1/26	0.00214	-6.14914	0.706	0.348
1/29	0.00267	-5.92600		
1/29	0.00214	-6.14914	0.800	0.223
2/ 2	0.00320	-5.74368		
2/ 2	0.00303	-5.80083	0.944	0.057
2/ 3	0.00214	-6.14914	0.706	0.348
2/ 4	0.00142	-6.55461	0.667	0.405
2/ 5	0.00107	-6.84229	0.750	0.288
2/ 6	0.00089	-7.02461	0.833	0.182
2/ 9	0.04093	-3.19597		
2/ 9	0.04022	-3.21351	0.983	0.018
2/10	0.03808	-3.26807	0.947	0.055
2/13	0.03861	-3.25415		
2/13	0.03755	-3.28219	0.972	0.028
2/14	0.03701	-3.29651	0.986	0.014
2/15	0.03559	-3.33573	0.962	0.039
2/16	0.03203	-3.44109	0.900	0.105
2/17	0.02491	-3.69240	0.778	0.251
2/18	0.01779	-4.02888	0.714	0.336
2/19	0.01246	-4.38555	0.700	0.357
2/20	0.00890	-4.72202	0.714	0.336
2/21	0.00712	-4.94517	0.800	0.223
2/24	0.00730	-4.92048		
2/24	0.00712	-4.94517	0.976	0.025
2/25	0.00658	-5.02313	0.925	0.078
2/26	0.00605	-5.10769	0.919	0.085
2/27	0.00587	-5.13754	0.971	0.030
2/28	0.00552	-5.20006	0.939	0.063
3/ 2	0.00552	-5.20006		
3/ 2	0.00534	-5.23285	0.968	0.033

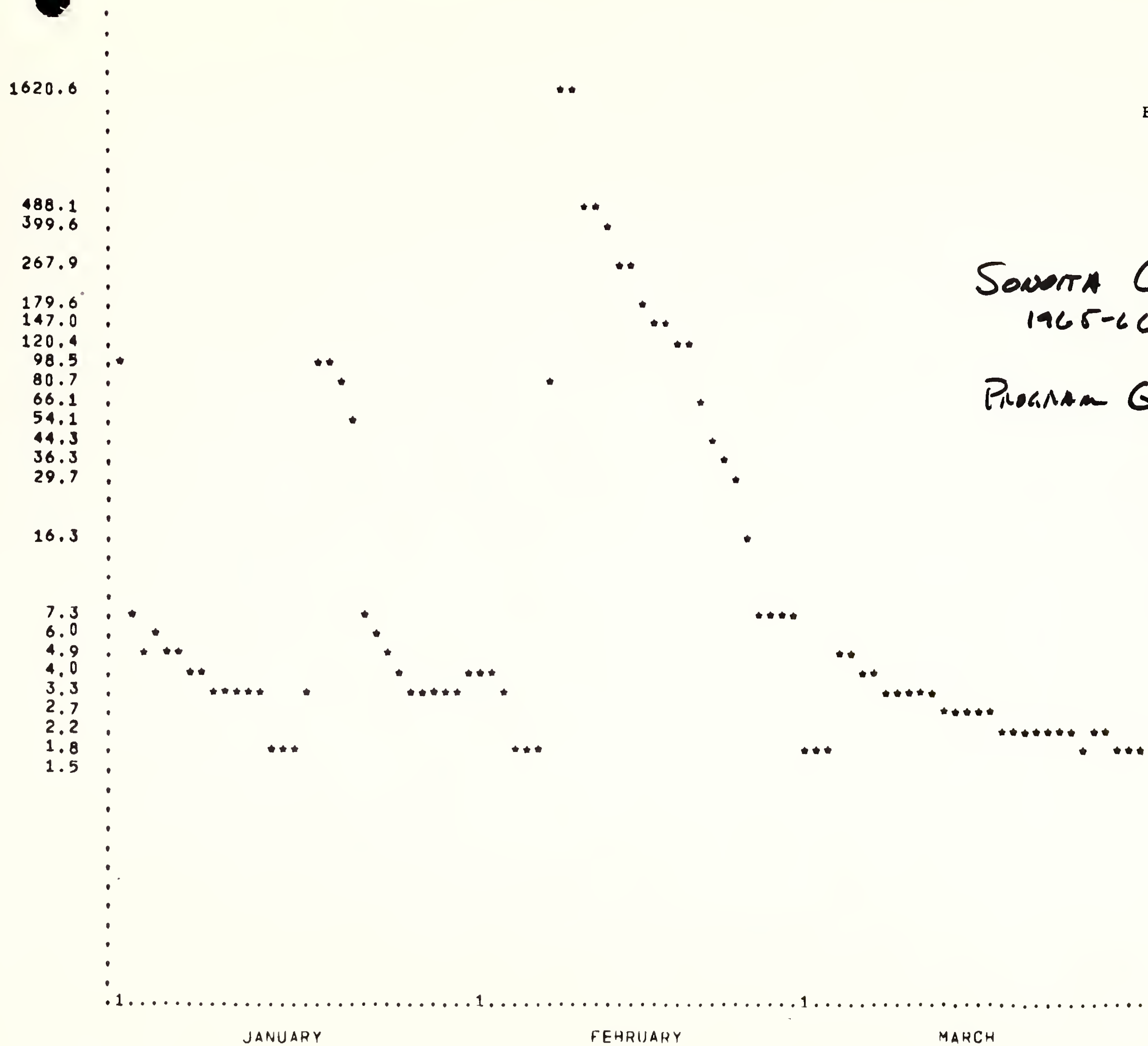
Exhibit 1 (cont)

1/24	0,00391	-5,54300	[illegible]	[illegible]
1/25	0,00303	-5,80083	0,773	0,258
1/26	0,00214	-6,14914	0,706	0,348
1/29	0,00267	-5,92600		
1/29	0,00214	-6,14914	0,800	0,223
2/ 2	0,00320	-5,74368		
2/ 2	0,00303	-5,80083	0,944	0,057
2/ 3	0,00214	-6,14914	0,706	0,348
2/ 4	0,00142	-6,55461	0,667	0,405
2/ 5	0,00107	-6,84229	0,750	0,288
2/ 6	0,00089	-7,02461	0,833	0,182
2/ 9	0,04093	-3,19597		
2/ 9	0,04022	-3,21351	0,983	0,018
2/10	0,03808	-3,26807	0,947	0,055
2/13	0,03861	-3,25415		
2/13	0,03755	-3,28219	0,972	0,028
2/14	0,03701	-3,29651	0,986	0,014
2/15	0,03559	-3,33573	0,962	0,039
2/16	0,03203	-3,44109	0,900	0,105
2/17	0,02491	-3,69240	0,778	0,251
2/18	0,01779	-4,02888	0,714	0,336
2/19	0,01246	-4,38555	0,700	0,357
2/20	0,00890	-4,72202	0,714	0,336
2/21	0,00712	-4,94517	0,800	0,223
2/24	0,00730	-4,92048		
2/24	0,00712	-4,94517	0,976	0,025
2/25	0,00658	-5,02313	0,925	0,078
2/26	0,00605	-5,10769	0,919	0,085
2/27	0,00587	-5,13754	0,971	0,030
2/28	0,00552	-5,20006	0,939	0,063
3/ 2	0.00552	-5.20006		
3/ 2	0.00534	-5.23285	0.968	0,033
3/ 3	0,00516	-5,26675	0.967	0,034
3/ 4	0,00463	-5,37595	0,897	0.109
3/ 5	0,00445	-5,41517	0,962	0.039
3/ 6	0,00409	-5,49855	0,920	0,083
3/ 7	0,00374	-5,58952	0.913	0.091
3/ 8	0,00356	-5,63832	0,952	0,049
3/ 9	0,00320	-5,74368	0,900	0,105
3/10	0,00285	-5,86146	0,889	0.118
3/11	0,00267	-5,92600	0,938	0,065
3/12	0,00249	-5,99499	0,933	0,069
3/13	0,00231	-6,06910	0.929	0.074
3/14	0,00214	-6,14914	0,923	0,080
3/25	0,00214	-6,14914		
3/25	0,00196	-6,23615	0.917	0,087
3/30	0,00214	-6,14914		
3/30	0,00196	-6,23615	0,917	0,087
3/31	0,00178	-6.33146	0,909	0,095
4/ 6	0.00214	-6.14914		

EXHIBIT 2

Sonoita Creek
1965-66

Program GS Plot



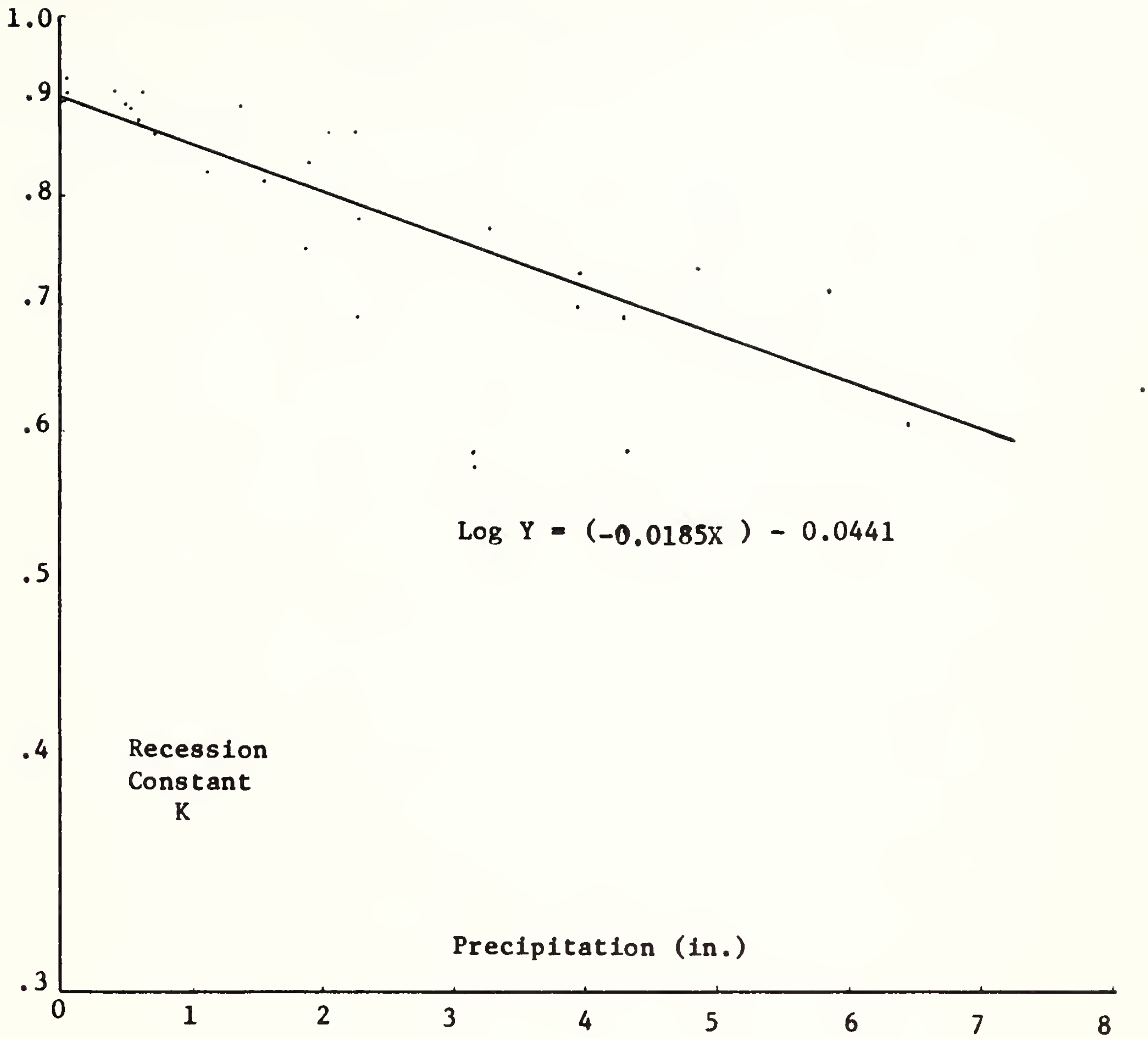
$$\ln K_r = \frac{(-0.0185\ P_m) - 0.0441}{0.43429}$$

Where:

K_r = Recession constant for month

P_m = Precipitation for month

While the recession constants were related to the seasonal precipitation patterns (storm intensity and duration), and the above relationship was considered more than adequate for the monthly simulation study.



Mean Monthly Recession
and
Monthly Precipitation
Sonoita Creek

No. 4

In-Channel Depletions

Summary and Conclusions:

In-channel depletions from the deep alluvial channels was accounted for in the simulation study. The 96 acres of alluvial bottoms within the Red Rock Watershed were delineated as two Hydrologic Response Units, 3A4 (14 acres) and 8B4 (82 acres). Subwatersheds 1 through 3 were routed into HRU 3A4 and subwatersheds 4 through 6 plus HRU's 3A4, and 8B1 were routed into HRU 8B4. Losses from riparian evapotranspiration were computed for the alluvial channel HRU's.

From seismic tests, the average depth of the streambed alluvium and terrace deposits was found to be 20 feet. Depth to the water table averaged 6 feet, with an average porosity of alluvium of 30 percent. An average depth to water of 12 feet was used in the simulation study. When the depth to water table was less than 12 feet, the excess water was routed out of the alluvial channels. Total water storage at the 12 foot level was 230 AF.

Because of the long routing interval (30 days) and short travel time within defined channels, (less than 1 hour), routing of surface water in efficient channels by the standard routing techniques was not used for a monthly simulation study. However, on a daily watershed simulation, routing of surface water would give important information on time lags and combined volumes of runoff.

Surface Water Routing.

Two floods on the Walnut Gulch Watershed were evaluated to determine the routing coefficients in alluvial channels in the Red Rock Watershed. The flood hydrographs used in the evaluation are given in Section No. 7 Design Storm-Flood.

A streamflow routing optimization computer program (No. 23-52-6231) developed by the Corp of Engineers was used on a CDC 3400 computer. The program written in Fortram II solves by successive approximations for any number of cases, in turn, for the optimum Muskingum routing coefficients, K and X, to reproduce observed outflow Hydrographs for a number of floods, given observed inflow and outflow hydrographs. The Muskingum equation is:

$$O_2 = O_1 + C1(I_1 - O_1) + C_2(I_2 - I_1)$$

Where:

$$C1 = 2(TRHR)/(2AK\ (1-X) + TRHR)$$

$$C_2 = (TRHR - 2AK(X))/(2AK\ (1-X) + TRHR)$$

Two reaches were evaluated: 1) From flume 11 to flume 8 and 2) Flume 6 to flume 1, of which two floods were evaluated in each reach. The physical characteristics of the watershed and each reach is given in Table 1. The channel characteristics from the Walnut Gulch Watersheds

Table 1. Watershed and Channel Characteristics

	Channel Reach	Channel Length (Miles)	Ave. Slope (%)	Ave. Chan. Width for "In-Bank" Flow (Ft.)	Roughness Coef. (n)	Watershed Upper Flume	Area (sq. mi.) Lower Flume
Flume	6 - 1	6.8	1.0	193	0.013	36.7	57.7
Flume	11 - 8	4.2	1.0	43	0.020	3.2	6.0

given in Table 1 were comparable to channel orders two and three, respectively, on the Red Rock Watershed.

The two floods were analyzed in two ways: 1) The two floods were combined and one set of coefficients extracted and 2) The two floods were analyzed separately and two sets of coefficients extracted. Exhibit 1. is the results of the combined floods.

Conclusions regarding the evaluation are:

1) The streamflow routing optimization program can be used to determine the Muskingum routing coefficients AK and X.

2) The routing coefficients on gaged channels can be extrapolated to other channels exhibiting similar hydraulic geometry.

3) The Muskingum method does not take into account transmission losses. In channels where transmission losses are significant (Red Rock Alluvial Channels) a storage basin with a given intake capability and water table will have to be simulated.

   When inflow-outflow hydrographs in alluvial channels are used, errors in AK and X will result. In this case AK can be adjusted by equating it with the travel time through the reach and X, which is a measure of the translatory component of the wave motion, can be adjusted by analyzing the characteristics of the outflow hydrograph.

4) When the routing time interval, TRHR, is much greater than AK, the advantages of routing for defining time-volume changes downstream become limited. Because of the low AK values in most reaches (less than 24 hours) it is concluded that routing on

anything greater than a 24 hour time interval or a daily simulation study would be of little advantage.

PSW II FOREST SERVICE
STREAMFLOW OPTIMIZATION TEST
RED ROCK SURVEY WALNUT GULCH DATA FLUME 6 TO 1

```
   TR NISTA  LSTA NFLDS NCOUB IPNCH      A      T1      T2      T3      T4      T5      T6
   10     1    -0     2    -0    -0     10       1
STA 1   COMP 1   STD ERR=     1787      1825     1809
STA 1   COMP 2   STD ERR=     1787      1825     1809
STA 1   COMP 3   STD ERR=     1788      1826     1809
X FOR STA 1   CHANGED FROM 0.200   TO 0.134
STA 1   COMP 1   STD ERR=     1776      1810     1795
STA 1   COMP 2   STD ERR=     1773      1807     1792
STA 1   COMP 3   STD ERR=     1769      1805     1789
AK FOR STA 1   CHANGED FROM   0.17   TO   0.25
STA 1   COMP 3   STD ERR=     1593      1682     1644
X FOR STA 1   CHANGED FROM 0.200   TO 0.300
STA 1   COMP 1   STD ERR=     1635      1750  .  1701
STA 1   COMP 2   STD ERR=     1629      1746     1697
STA 1   COMP 3   STD ERR=     1624      1743     1693
AK FOR STA 1   CHANGED FROM   0.25   TO   0.28
STA 1   COMP 3   STD ERR=     1577      1713     1656
X FOR STA 1   CHANGED FROM 0.200   TO 0.300
STA 1   COMP 1   STD ERR=     1577      1713     1656
STA 1   COMP 2   STD ERR=     1571      1710     1651
STA 1   COMP 3   STD ERR=     1565      1706     1647
AK FOR STA 1   CHANGED FROM   0.26   TO   0.28
STA 1   COMP 3   STD ERR=     1714      1870     1804
X FOR STA 1   CHANGED FROM 0.200   TO 0.201
STA 1   COMP 1   STD ERR=     1689      1824     1767
STA 1   COMP 2   STD ERR=     1689      1820     1764
STA 1   COMP 3   STD ERR=     1682      1816     1759
AK FOR STA 1   CHANGED FROM   0.28   TO   0.41
STA 1   COMP 3   STD ERR=     1414      1616     1532
X FOR STA 1   CHANGED FROM 0.209   TO 0.201
STA 1   COMP 1   STD ERR=     1410      1616     1530
STA 1   COMP 2   STD ERR=     1402      1610     1524
STA 1   COMP 3   STD ERR=     1394      1605     1517
AK FOR STA 1   CHANGED FROM   0.41   TO   0.41
STA 1   COMP 3   STD ERR=     1409      1616     1530
X FOR STA 1   CHANGED FROM 0.200   TO 0.201
STA 1   COMP 1   STD ERR=     1410      1616     1530
STA 1   COMP 2   STD ERR=     1402      1610     1524
STA 1   COMP 3   STD ERR=     1394      1605     1517
AK FOR STA 1   CHANGED FROM   0.41   TO   0.41
STA 1   COMP 3   STD ERR=     1409      1616     1530
X FOR STA 1   CHANGED FROM 0.200   TO 0.201
STA 1   COMP 1   STD ERR=     1410      1616     1530
FLOOD STARTING     9    10 1967 1600   RATIO COMP TO OBS VOL=  1.23   RTIOL=    0.000
```

PRIOD	ROUTD Q	LOCAL	TOTAL	OBS Q	ROUTD1	ROUTD2	ROUTD3	ROUTD4	ROUTD5	RC
1	50	0	50	0	50					
2	50	0	50	0	50					
3	191	0	191	0	191					
4	436	0	436	0	436					
5	1748	0	1748	0	1748					
6	2935	0	2935	0	2935					
7	3725	0	3725	0	3725					
8	4157	0	4157	0	4157					
9	4154	0	4154	2800	4154					
10	3650	0	3650	4200	3650					
11	2785	0	2785	4325	2785					
12	2027	0	2027	3500	2027					
13	1433	0	1433	2380	1433					
14	1002	0	1002	1900	1002					
15	711	0	711	1350	711					
16	516	0	516	840	516					
17	381	0	381	625	381					
18	288	0	288	500	288					
19	216	0	216	480	216					
20	166	0	166	400	166					
21	129	0	129	315	129					
22	99	0	99	275	99					
23	79	0	79	245	79					
24	66	0	66	210	66					
25	55	0	55	175	55					
26	47	0	47	160	47					
27	40	0	40	150	40					

16	516	0	516	840	516
17	381	0	381	625	381
18	288	0	288	500	288
19	216	0	216	480	216
20	166	0	166	400	166
21	129	0	129	315	129
22	99	0	99	275	99
23	79	0	79	245	79
24	66	0	66	210	66
25	55	0	55	175	55
26	47	0	47	160	47
27	40	0	40	150	40
28	36	0	36	140	36
29	32	0	32	125	32
30	27	0	27	115	27
31	24	0	24	100	24
32	14	0	14	95	14

Exhibit 1 (cont.)

FLOOD STARTING 7 22 1967 1900 RATIO COMP TO OBS VOL= 1.26 RTIOL= 0.000

PERIOD	ROUTD Q	LOCAL	TOTAL	OBS Q	ROUTD1	ROUTD2	ROUTD3	ROUTD4	ROUTD5
1	20	0	20	0	20				
2	20	0	20	0	20				
3	28	0	28	0	28				
4	620	0	620	0	620				
5	2783	0	2783	0	2783				
6	4298	0	4298	0	4298				
7	4520	0	4520	0	4520				
8	4090	0	4090	0	4090				
9	3430	0	3430	0	3430				
10	2755	0	2755	4350	2755				
11	2150	0	2150	4300	2150				
12	1583	0	1583	3080	1583				
13	1117	0	1117	2450	1117				
14	789	0	789	2000	789				
15	572	0	572	1520	572				
16	426	0	426	1000	426				
17	331	0	331	700	331				
18	258	0	258	470	258				
19	199	0	199	340	199				
20	139	0	139	300	139				
21	83	0	83	275	83				
22	50	0	50	250	50				
23	30	0	30	240	30				
24	18	0	18	230	18				
25	11	0	11	225	11				
26	6	0	6	220	6				
27	4	0	4	210	4				
28	2	0	2	200	2				
29	1	0	1	190	1				
30	1	0	1	180	1				
31	0	0	0	175	0				
32	0	0	0	170	0				
33	0	0	0	160	0				
34	0	0	0	150	0				
35	0	0	0	140	0				
36	0	0	0	125	0				
37	0	0	0	110	0				
38	0	0	0	100	0				
39	0	0	0	90	0				
40	0	0	0	60	0				
41	0	0	0	50	0				
42	0	0	0	25	0				

STA	AK	X	C1	C2	NRCHS
1	0.41	0.201	0.402	0.000	7

ALTERNATIVE COEFFICIENTS (SEE EQUA 14 AND PLATE 2--EM 1110-2-1408)

STA	C1	C2	C3	C4	C5	C6	C7	NRCHS
1	0.000	0.402	0.240	0.144	0.086	0.051	0.076	7

NO. 5

ANALYSIS OF FLOW

ON

SONOITA CREEK USGS GAGE

Summary and Conclusions:

An analysis of a Seismic investigation conducted at the USGS gaging site on Sonoita Creek at Circle Z Ranch showed the gage to be 11% in error for median annual flow.

Lake Patagonia is predicted to fill in 147 days from Feb. 9, 1969. The discrepancy of filling time, and estimated time using USGS records can be accounted for by adding the amount of water contributed below the gage from an area of 21 sq. miles, and the 1.42 Ac. ft. per day flowing in the alluvium underneath the gage.

ANALYSIS OF FLOW ON SONOITA CREEK

AT U.S.G.S. GAGE NEAR

PATAGONIA, ARIZ.

The flow of Sonoita Creek is measured by the U.S.G.S. at a gaging site in the vicinity of Circle Z Ranch approximately 4.5 miles below the town of Patagonia, Ariz. Data are available for the periods June 1, 1930 through December 31, 1933, and July 1, 1935 through September 30, 1966. (See Section 10 for years 1936 through 1967).

The U.S.G.S. gage is located on an old abandoned railroad abutment in an abrading channel. There is no artificial control at the gage site, and the rating curve for the station is developed from current meter measurements 100 ft. downstream from the stilling well. The gaging site is located just below a curve in the stream bed, and because of the subsequent shift in the control due to sand bars, it is necessary to provide a separate channel to the stilling well in order to provide a continuous record.

Current meter measurements made by F. Brown and D. Anderson Feb. 6, 1969 showed a flow of 9 cfs passing the gage as measured 100 ft. downstream.

A seismic investigation was made at the USGS site on Sonoita Creek Feb. 7, 1969 by H. Brown, Geologist for PSW II. The results of this seismic work show that there is 36 feet of unconsolidated material beneath this gaging site. (See Geology-Appendix VI). The width of this

unconsolidated alluvium was 95' as measured between the railroad abutments. This is 3420 sq. ft. of saturated alluvium which has a coefficient of permeability of 5,000 gallons per day per square foot. The terrace deposits on both sides of the channel measured 1050 feet, which gives 30,464 sq. ft. of alluvium with a coefficient of 955 gallons per day per square foot.

Solving Darcy's equation for flow through these saturated media shows that there is 518 Ac. ft. of water per year by-passing the gage which has up to now been unaccounted for. The median surface discharge for Sonoita Creek at the U.S.G.S. gage is 4,640 AF per year. The 518 AF flowing underneath the gage represents an error of 11.2 percent in the median flow.

Lake Patagonia Inflow Records

1. On September 25, 1968 the gates were closed on Lake Patagonia and filling began.

2. As of February 9, 1969, 3,294 Ac. ft. have been stored in the reservoir.

3. Outflow from Lake Patagonia to satisfy the downstream water rights has been 1,096 AF from September 25, 1968 to February 9, 1969.

4. Mean daily inflow for 137 days is 24 AF per day or 12 cfs.

5. Total storage for Lake Patagonia as of February 9, 1969 is 2200 Ac. ft.

6. At the present rate of filling, it will take 147 days from February 9, 1969 to reach spillway level in Lake Patagonia.

7. Using the figures of the average daily flow passing the USGS gage for 137 days of reservoir filling into Lake Patagonia gives 544 Ac.ft.

8. The area of 21 sq. mi. below the USGS gage contributing to the reservoir filling to Lake Patagonia for the 137 days gives 367 Ac. ft.

9. Flow going underneath the USGS gage amounts to 194 Ac. ft. for the 137 days of reservoir filling.

10. Adding the 367 Ac. ft. contributed below the gage and the 194 Ac. ft. going underneath the gage gives a total of 561 Ac. ft.

We feel that the 11% error at the gage is significant and has certainly contributed to the fast filling rate into Lake Patagonia.

Subsurface Flow at Sonoita

Creek Gage

Width of terrace deposits on which gage is situated	= 1050 ft.
Width of stream bottom alluvium	= 95 ft.
Depth to bedrock 100 ft. downstream from gage (seismic tests)	= 36 ft.
Cross-sectional area of stream bottom alluvium	= 3,420
Cross-sectional area of terrace deposits	=30,464
Hydraulic gradient of water table	= 57 ft/mi or 0.01 ft/ft.
Coefficient of permeability for stream bottom alluvium[1/]	= 5,000 ga/day/ft^2
Coefficient of permeability for terrace deposits[2/]	= 955 ga/day/ft^2

Solving Darcy's Law:[3/]

$$Q = KAI$$

Where Q = Discharge

K = Coef. of permeability

A = Area

I = Hydraulic Gradient

Subsurface discharge through stream bottom alluvium	= 0.26 cfs/day, 0.53 AF/day
Subsurface discharge through terrace deposits	= 0.45 cfs/day, 0.89 AF/day
Total subsurface discharge	= 0.71 cfs/day, 1.42 AF/day
Annual subsurface discharge	= 518 AF
Mean annual surface discharge (Gage records, 1936 to 1967)4/	= 5,723 AF
Median surface discharge (same period)	= 4,640 AF
Annual subsurface discharge as percent of median surface discharge	= 11.2%
Total mean annual discharge from Sonoita Creek Watershed above gage	= 6,241 AF
Annual subsurface discharge as percent of mean annual surface discharge	= 9.1%

1/ U. S. Geological Survey, Well Pump Tests in Sycamore Creek, Phoenix Office.

2/ Nassereddin, M. T., 1967, *Hydrogeological Analysis of Groundwater Flow in Sonoita Creek Basin, Santa Cruz County, Arizona.* Thesis, U. of Ariz.

3/ Todd, David K., 1967. *Ground Water Hydrology.* John Wiley and Sons, 326 p.

4/ U. S. Geological Survey, *Surface Water Supply Records.*

DISCHARGE MEASUREMENT NOTES

Stream: Sonoita Creek   Discharge: 8.96 cfs

WPJ: -   Date: 2/6/69

Location: USGS Gage = 100' downstream

Flow Char.: -

Party: Anderson & Brown   Gage Ht: -

STATION	ANGLE COEF	DIST. FROM INIT. PT (ft)	DEPTH (ft)	METER READING (Per 50 seconds) V_1 (0.6 d)	METER READING (Per 50 seconds) V_2 (- d)	DISCHARGE (cfs)
		2.0				
1	1	3.0	0.25	43	-	
2	1	5.0	0.35	74	-	
3	1	6.5	0.50	164	-	
4	1	8.0	0.60	205	-	
5	1	9.5	0.50	141	-	
6	1	11.0	0.35	27	-	
7	1	12.0	0.30	39	-	
8	1	13.5	-	-		
						8.96

DISCHARGE MEASUREMENT NOTES

Stream: Sonoita Creek   Discharge: 9.22 cfs

WPJ: -   Date: 2/6/69

Location: Circle Z Ranch

Flow Char.: -

Party: Anderson & Brown   Gage Ht: -

STATION	ANGLE COEF	DIST. FROM INIT. PT (ft)	DEPTH (ft)	METER READING (Per 50 seconds) V_1 (0.6 d)	METER READING (Per 50 seconds) V_2 (- d)	DISCHARGE (cfs)
		0				
1	1	1.5	0.25	65	-	
2	1	2.5	0.25	82	-	
3	1	4.0	0.30	98	-	
4	1	6.0	0.35	114	-	
5	1	8.0	0.40	128	-	
6	1	9.5	0.50	128	-	
7	1	11.5	0.65	103	-	
8	1	12.5	0.62	96	-	
		14.0				9.22

Exhibit 1

PERTINENT DATA

LAKE PATAGONIA

Elevation Top of Dam	3784.47	
Stream Bed Elevation at Dam Axis	3681 ±	
Max. Depth at N.W.S.	85 Ft.±	
Elevation of Spillway Crest	3765.77	
Elevation of N.W.S.	3765.77	
Elevation of M.W.S.	3779.17	
Surface Area (N.W.S.)	260 Ac.	
Surface Area (M.W.S.)	334 Ac.	
Storage (N.W.S.)	7650 Ac.Ft.	
Storage (M.W.S.)	11,420 Ac. Ft.	
Length of lake (N.W.S.)	12,800 Ft.	
Length of Shoreline (N.W.S.)	43,550 Ft.	
Drainage Area	230 sq. miles	
Probable 1000 year storm inflow	29,300 C.F.S.	

LENGTH @ CREST 915 FT.

DAM DATUM TO M.S.L.
ADD 3576.77 TO DAM DATUM

Exhibit 2

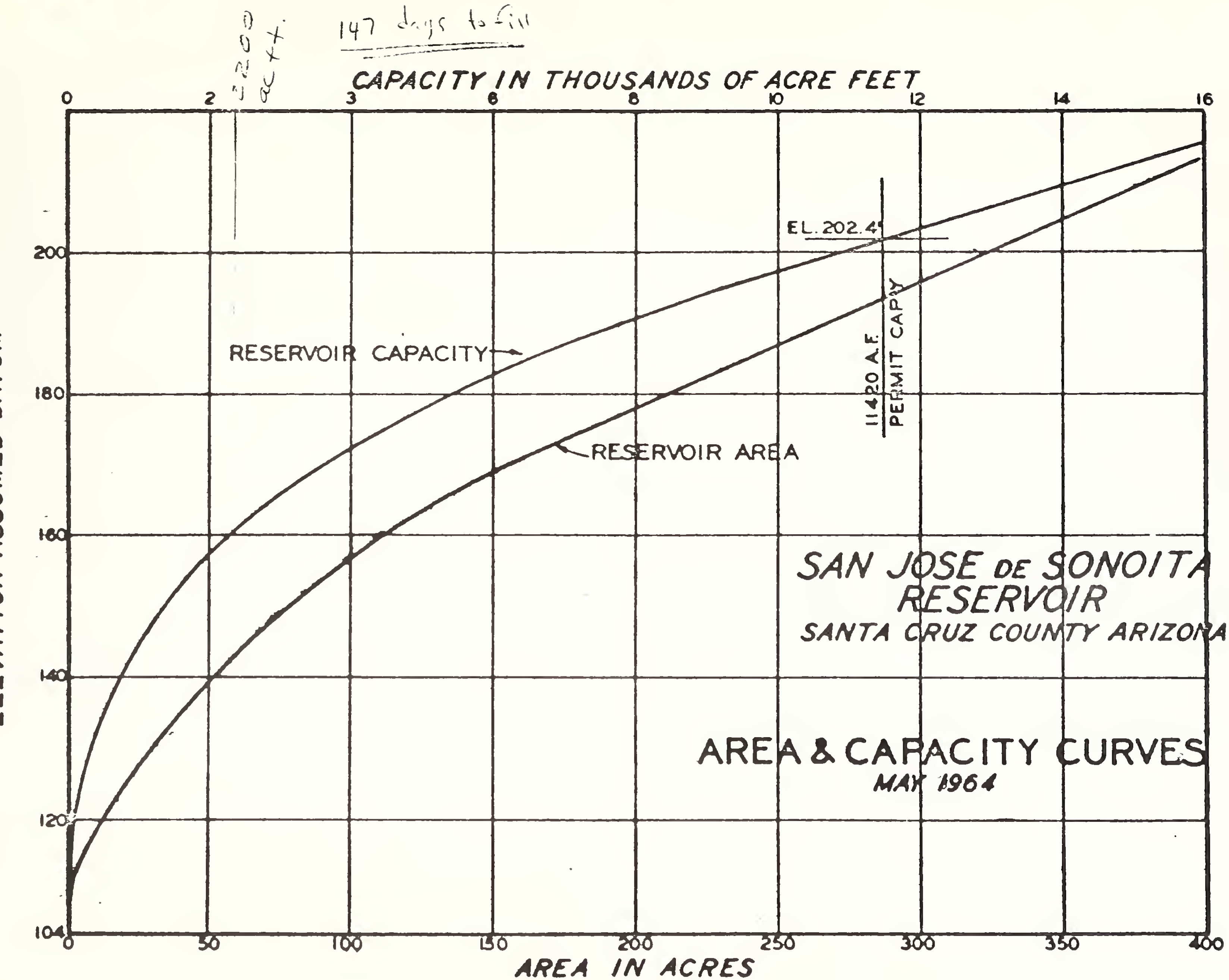

147 days to fill
2200 ac ft
CAPACITY IN THOUSANDS OF ACRE FEET
0
2
3
6
8
10
12
14
16
EL. 202.4'
11420 A.F.
PERMIT CAPY
RESERVOIR CAPACITY
RESERVOIR AREA
ELEVATION ASSUMED DATUM
200
180
160
140
120
104
SAN JOSE DE SONOITA
RESERVOIR
SANTA CRUZ COUNTY ARIZONA
AREA & CAPACITY CURVES
MAY 1964
0
50
100
150
200
250
300
350
400
AREA IN ACRES

Figure 1

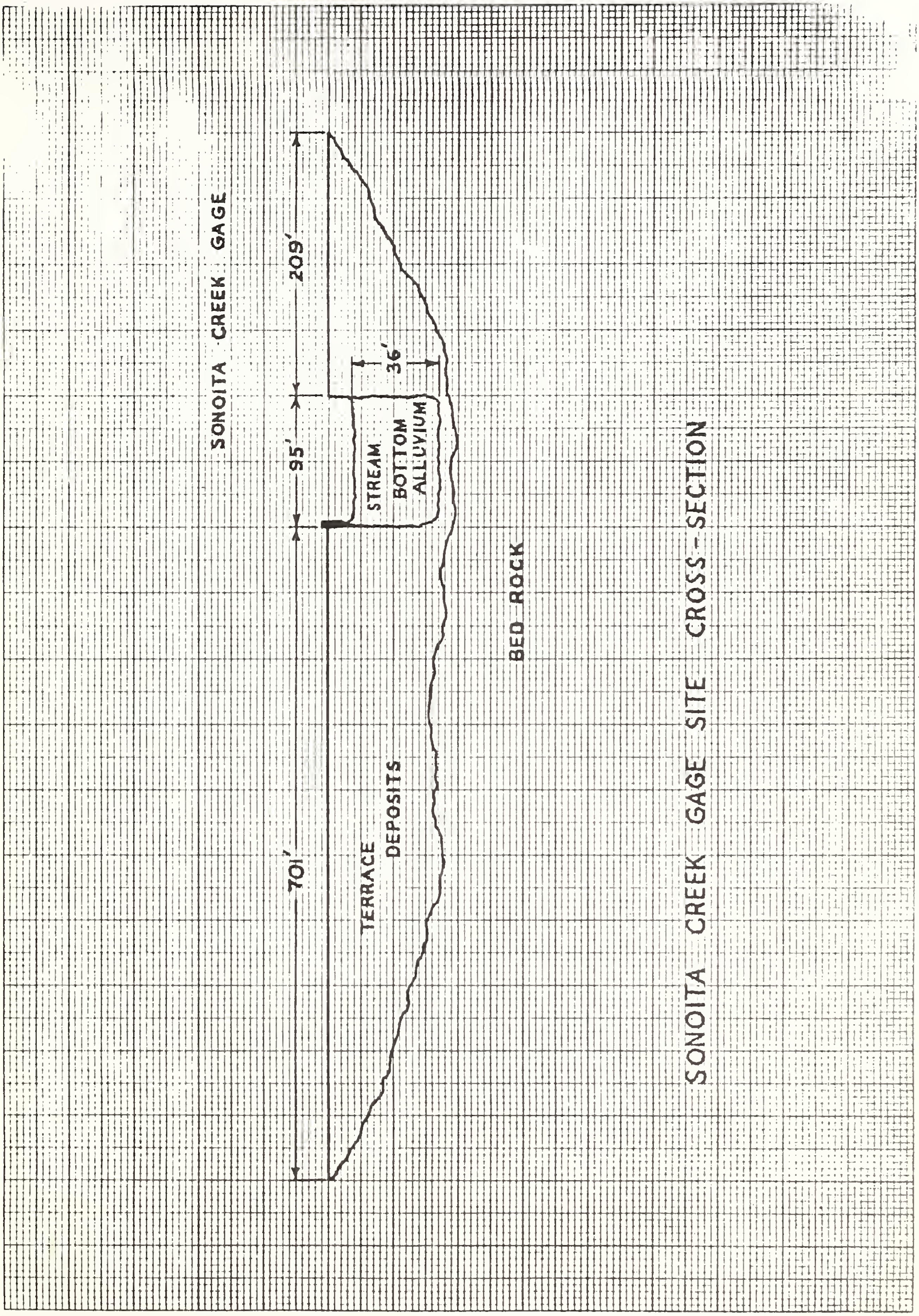

SONOITA CREEK GAGE
209'
36'
95'
STREAM BOTTOM ALLUVIUM
701'
TERRACE DEPOSITS
BED ROCK
SONOITA CREEK GAGE SITE CROSS-SECTION

Figure 2

NO. 6

SURFACE WATER ANALYSIS

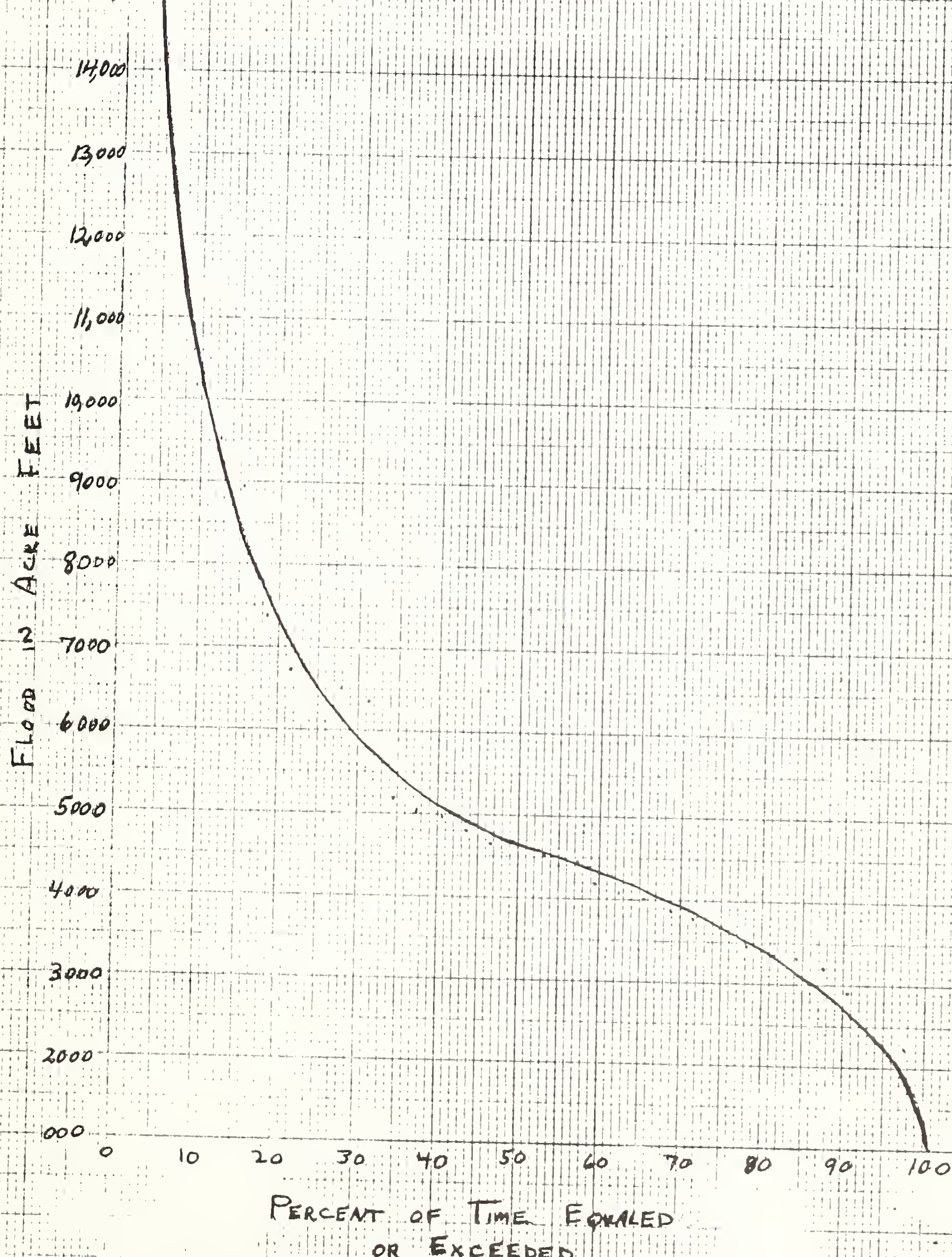
Summary and Conclusions

Gaged runoff from the Sonoita Creek Watershed averages 0.51 inches per year or 5,723 AF per year. Because of sub-surface flow under the gage, mean annual flow from the Sonoita Creek Watershed is probably closer to 6,200 AF per year.

Using the watershed simulation model over a 32 year period (1936-1967), mean annual runoff from the Red Rock Canyon Watershed above damsite "A" is 0.50 inches or 747 AF. On the average, a dam constructed at Site "A" can be expected to fill in 8-1/2 years. The range in filling time varies from 1 month to 19 years. Once the dam is filled, the surface area of the lake will average 105 acres in size. The average volume of spill and leakage per year is respectively 364.6 AF and 73.6 AF. Annual lake evaporation averaged 53.1 inches. However, because of a reduction of 16.1 inches of evapotranspiration from inundation of the lake, net evaporation loss averages 37 inches or 285 AF per year.

Because of fractured geologic material, a minimum of 73.6 AF/year or 6.13 AF/month will occur even with a tightly sealed dam. This amounts to a minimum leakage of 2 percent of the volume per year. The results of the simulation study (Table 1) show that during the 32 year period, 34 months or 9 percent of the time, runoff from Red Rock Canyon was less than 6.13 AF/month. In other words, during extreme low flow periods, runoff from Red Rock Canyon will be greater with the reservoir than without because of the minimum leakage.

Figure 1
Annual
Flow-Duration Curve
for
Sonoita Creek



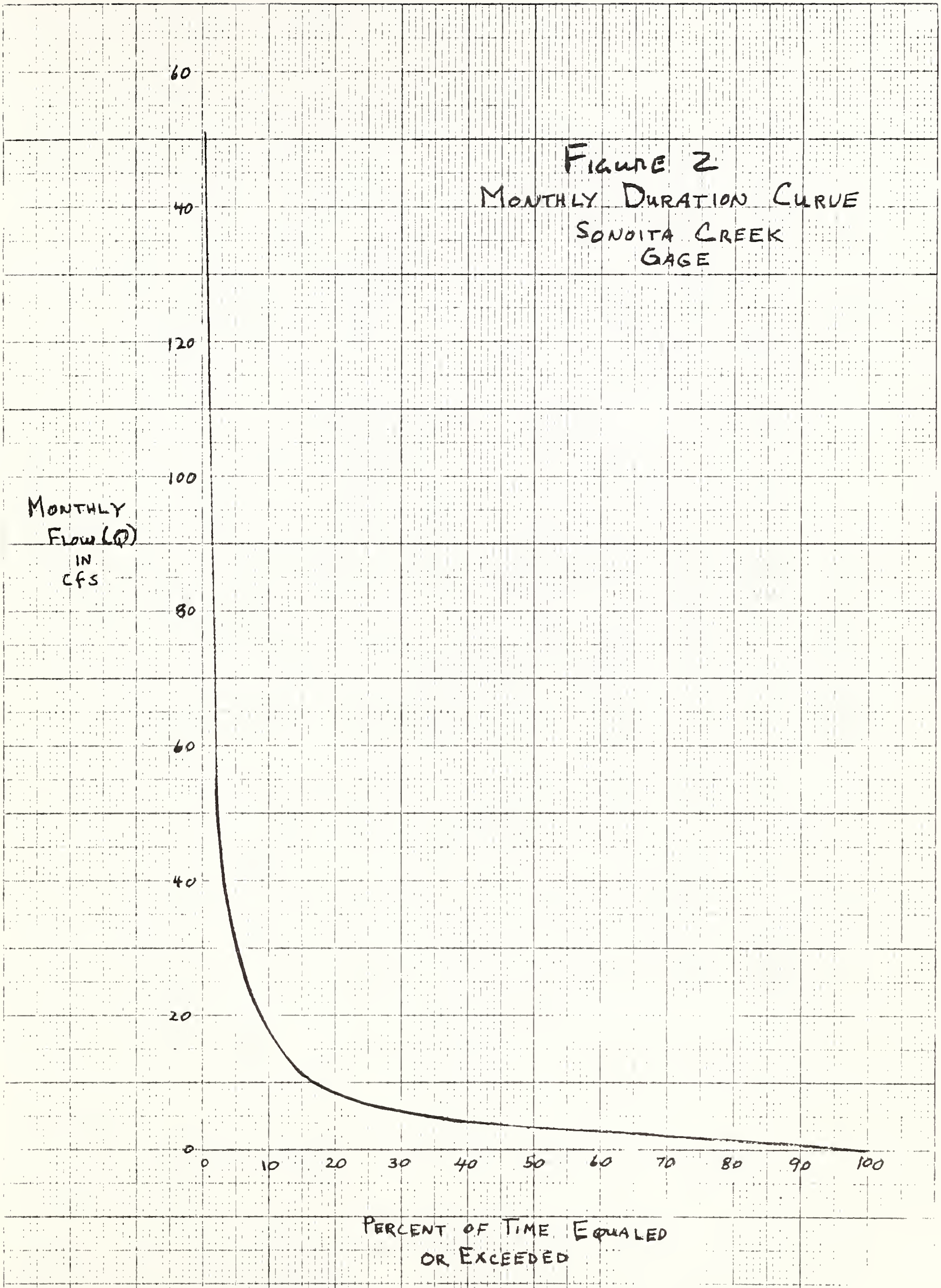
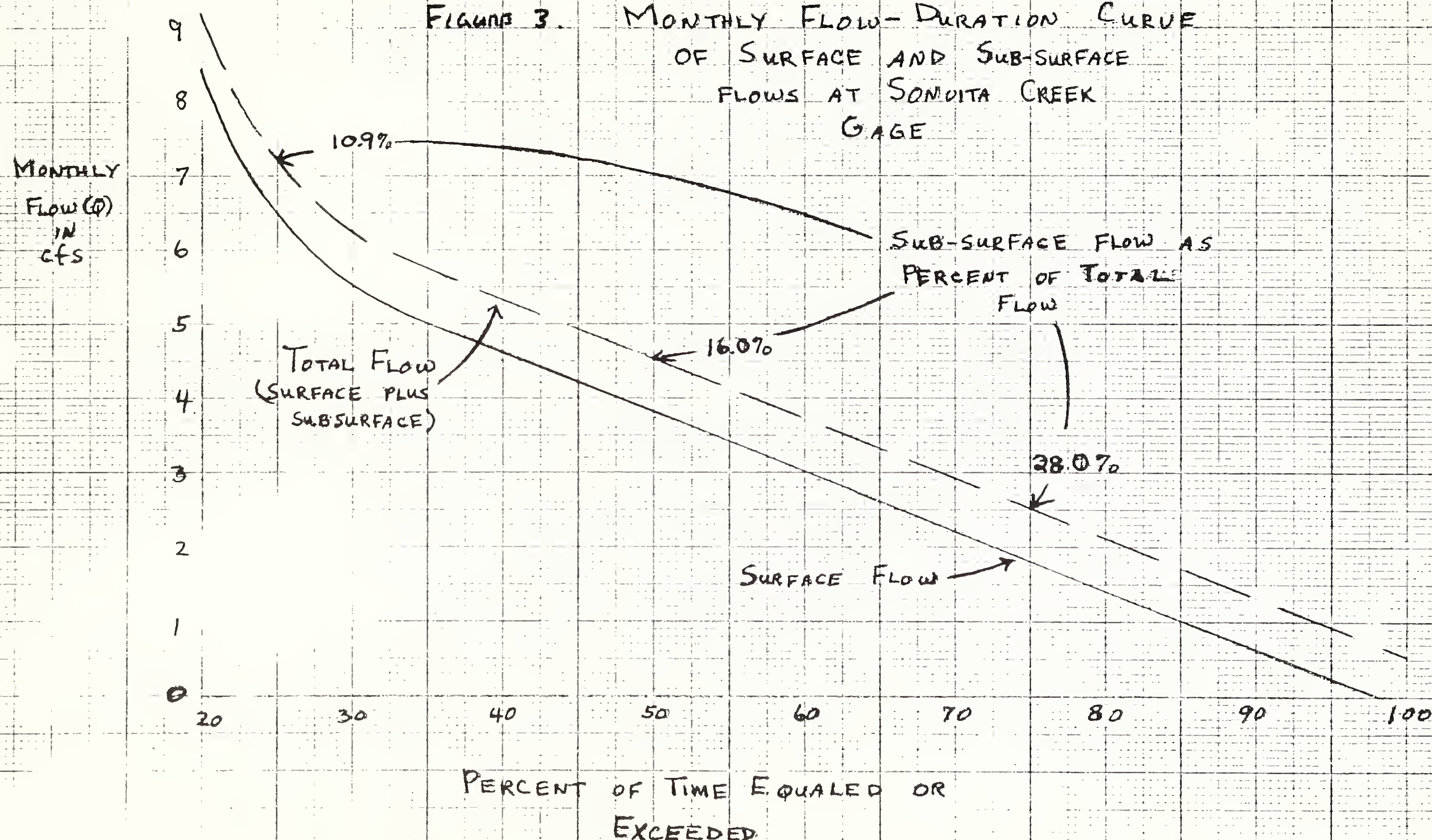


Figure 2
Monthly Duration Curve
Sonoita Creek Gage

Figure 3. Monthly Flow-Duration Curve of Surface and Sub-Surface Flows at Sonoita Creek Gage



Over the same 32 year period, increases in water yield from vegetation manipulation in the Patagonia and Santa Rita Mountains were computed at 89 AF per year above the town of Patagonia and Bird Sanctuary and 181 AF per year below the Bird Sanctuary and above Lake Patagonia. In addition to increased yield, a greater portion of the runoff following treatment will come during the low flow months.

If a dam is constructed at Red Rock Canyon, Site "A" and the potentially treatable areas are converted to grass, the net effect on the Bird Sanctuary will be a 29 percent reduction of the mean annual flow contributed by the Red Rock Canyon Watershed, and the effect on Lake Patagonia will be a 4 percent reduction of the mean annual flow contributed by Red Rock Canyon.

SONOITA CREEK WATERSHED

Analysis of the U.S.G.S. Sonoita Creek gage records from 1936 to 1967 gives a mean annual flow of 5,723 AF per year or 0.51 inches per year and a median runoff of 4,640 AF per year or 0.42 inches. Figures 1 and 2 give respectively an annual flow-duration curve in acre-feet and a monthly curve in cfs.

Analysis of the U.S.G.S. gage site (discussed in Appendix 1, No. 9) indicated that sub-surface flow under the gage is 11.2 percent of median surface discharge. Figure 3, which gives the monthly flow duration curve for surface and sub-surface flow, shows that on a monthly basis, the gage underestimates runoff by 16 percent.

RED ROCK CANYON WATERSHED

Several methods of analysis were used to estimate runoff from ungaged Red Rock Canyon. The first method was by area adjustment and the second by the watershed simulation model.

WATERSHED SIMULATION STUDY

Table 1 gives mean monthly flow in acre feet from 1936 to 1967 from the simulation study (the simulation model is discussed in Appendix 1, No. 2). Mean annual runoff was computed at 747 AF or 0.50 inches.

Table 2 gives the results of the reservoir filling analysis over the same 32 year period. The analysis was conducted computing the thirty-two years of record, 32 times, in the following sequence: 1936 through 1967, 1937 through 1967 and 1936, 1938 through 1967, 1936 and 1937, etc. The above sequence was done twice: 1) beginning with empty reservoir and 2) beginning with full reservoir. Exhibit 1 is an example computer print-out.

TREATABLE AREAS IN THE SANTA RITA AND PATAGONIA MOUNTAINS

Simulation of 32 years of runoff from the treatable areas shows a potential increase in water yield of 270 AF/year. 89 AF will be delivered above the bird sanctuary and Patagonia and 181 AF will be delivered below the bird sanctuary and out above Lake Patagonia. Figure 6 shows that in addition to increases in runoff a greater percentage of total runoff will come during the low flow months of May, June and October.

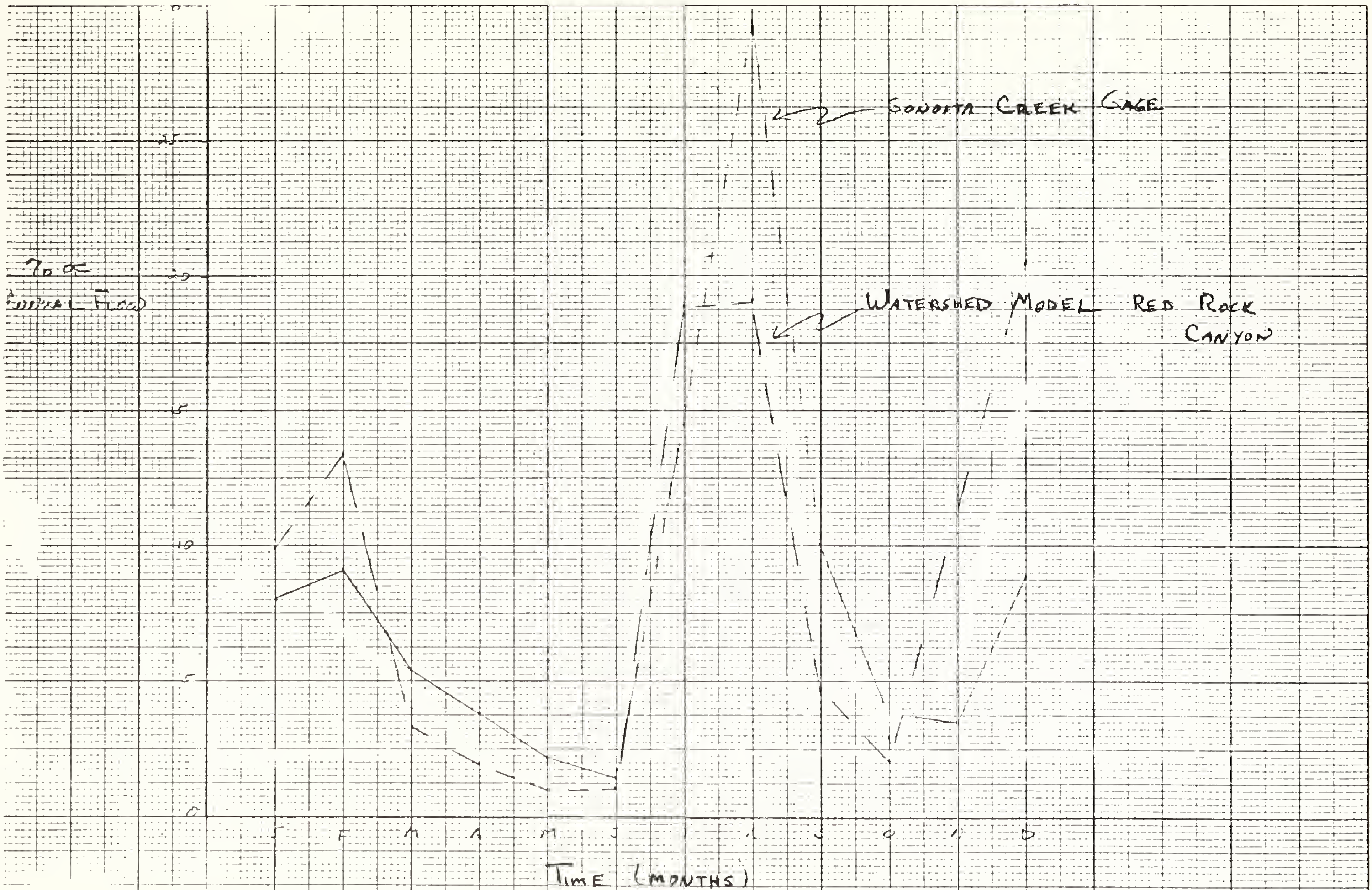


Fig 4 Monthly Flow as Percent of Annual Flow using a 32 year Average

Area Adjustment of Mean Annual Runoff

Mean annual runoff can be related to area with the following proportion:*

$$Q \propto A^{x}$$

Where:

Q = mean annual runoff

A = area

x = coefficient

From Walnut Gulch data the coefficient was found to be -0.239. Using the Walnut Gulch coefficient, and mean annual flow from Sonoita Creek, the following equation was used for an area adjustment of mean annual flow from Red Rock Canyon:

$$Q = 1.773\, A^{-0.239}$$

Where:

Q = mean annual runoff (inches)

A = area (sq. mi.)

Using the above equation, mean annual flow from Red Rock Canyon is 1,200 AF or 0.81 inches. Using a linear adjustment of 13.3 percent of the watershed yielding 13.3 percent of the mean annual flow, the 5,723 AF of annual runoff at the USGS gage is adjusted to 761 AF.

*Leopold, L. B., et. al. 1964. Fluvial Processes in Geomorphology. Freeman and Co., San Francisco, 522 p.

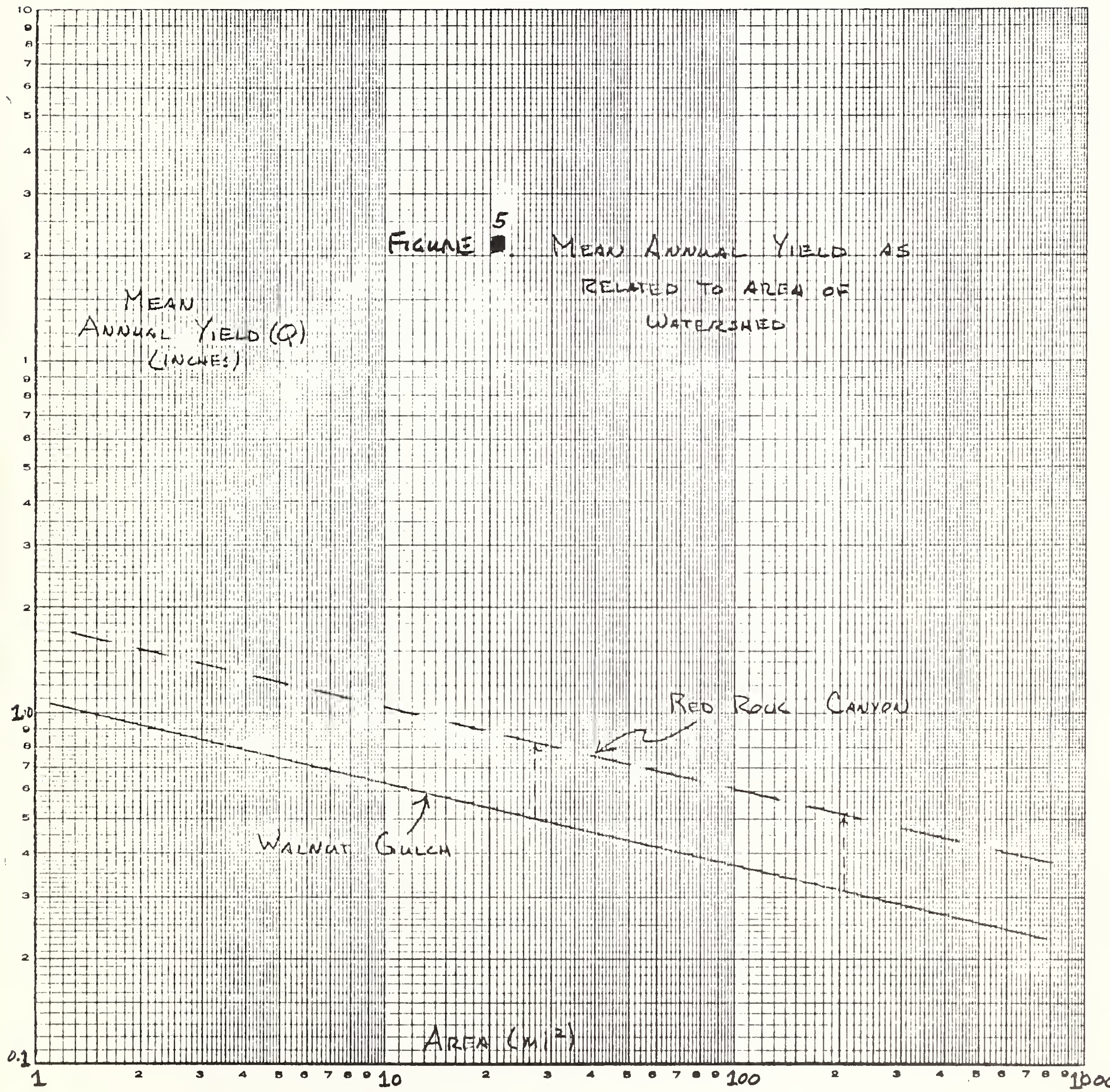
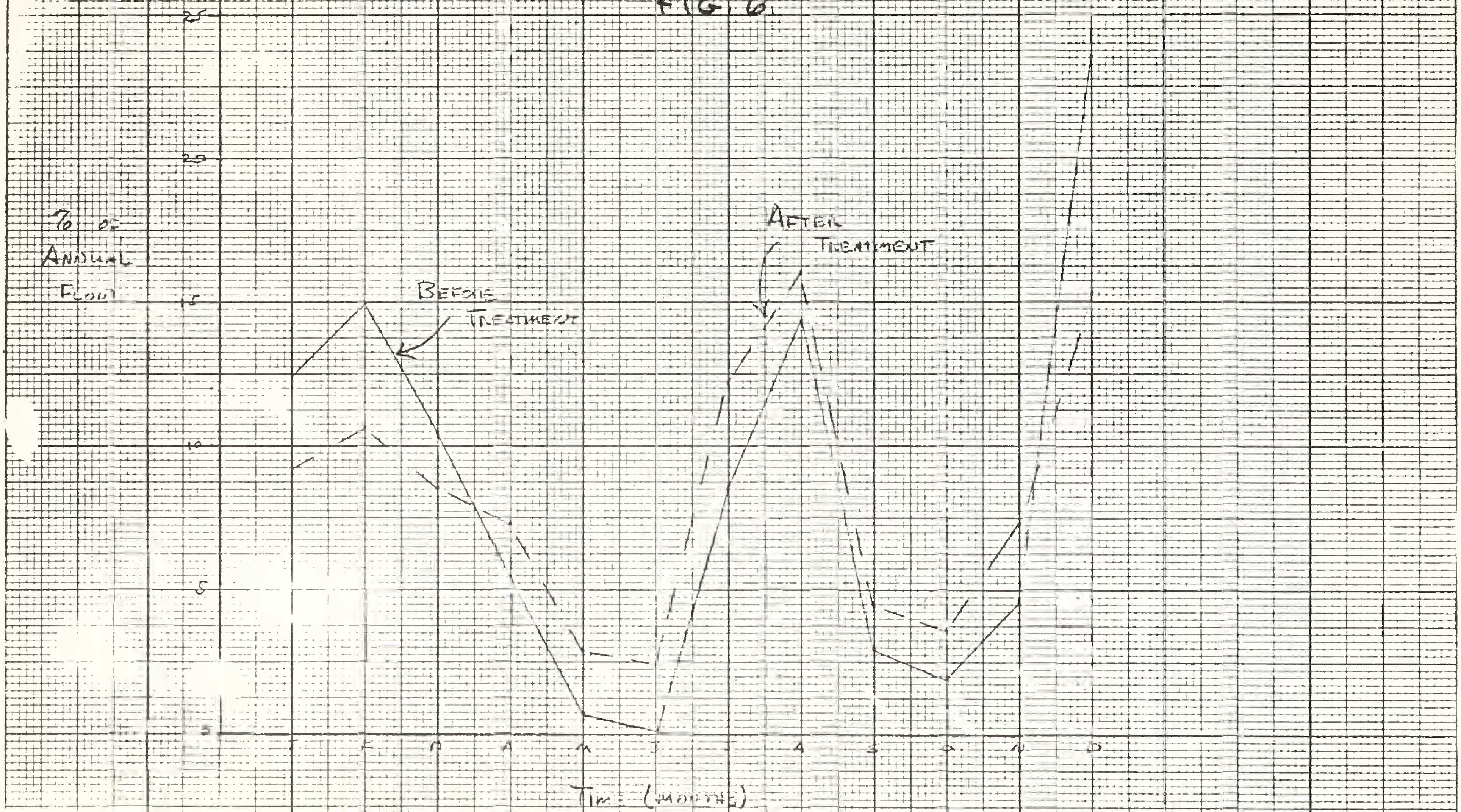


FIGURE 5. MEAN ANNUAL YIELD AS RELATED TO AREA OF WATERSHED
MEAN ANNUAL YIELD (Q) (INCHES)
RED ROCK CANYON
WALNUT GULCH
AREA (MI²)
10
1
1.0
0.1
1
10
100
1000

FIG. 6.



...THLY FLOW AS PERCENT OF ANNUAL FLOW BEFORE AND AFTER TREATMENT ...
... 52 YEAR AVERAGE — FOR ... AND ...

Table 1. Mean Monthly Flow (AF) - Red Rock Canyon: From Watershed Simulation Study

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1937	9.80	18.80	24.40	52.73	30.11	33.75	10.02	8.65	8.53	37.70	47.32	25.41
1938	17.42	7.78	25.74	19.60	27.24	23.96	7.22	7.03	14.52	27.63	59.05	13.25
1939	6.73	6.58	18.35	22.47	44.81	17.73	6.17	5.95	5.87	31.11	51.35	20.40
1940	14.66	9.03	10.76	9.32	51.74	14.23	5.22	5.14	26.97	39.20	39.23	28.35
1941	4.68	14.96	63.88	46.12	53.78	36.90	46.67	14.44	5.71	31.83	29.33	38.66
1942	9.77	4.40	37.50	22.00	31.82	16.09	35.74	4.12	3.94	19.99	16.94	13.30
1943	10.69	3.70	3.63	19.34	3.69	3.54	3.47	3.39	9.42	26.28	73.32	21.90
1944	7.24	4.48	11.76	12.81	38.22	41.53	17.16	4.21	4.06	15.49	42.09	18.46
1945	7.25	27.80	41.01	31.36	19.76	34.80	10.75	3.53	3.42	35.72	60.36	10.40
1946	24.98	3.70	3.63	34.37	12.57	9.30	4.14	3.40	3.33	47.94	31.51	95.39
1947	19.87	17.76	10.14	11.40	9.49	7.07	6.26	7.80	6.07	27.75	39.03	16.32
1948	7.21	16.17	14.60	6.40	35.00	15.11	5.26	5.07	4.96	60.82	53.80	23.92
1949	7.27	5.25	25.41	55.71	42.73	30.61	13.22	4.88	4.84	84.95	27.48	37.36
1950	11.01	6.24	38.69	25.33	26.72	9.36	5.57	5.42	5.39	1873.86	27.34	22.49
1951	10.69	10.46	10.24	35.51	18.01	13.09	23.35	9.42	9.23	39.00	85.01	24.73
1952	34.18	26.99	41.36	34.80	24.80	22.58	38.77	12.59	14.79	42.35	141.93	20.59
1953	10.82	31.94	30.82	17.62	35.08	27.66	9.89	9.52	9.37	189.66	31.56	10.80
1954	10.61	10.39	10.17	23.46	10.02	46.73	9.65	18.10	17.73	649.71	283.89	18.91
1955	12.03	10.57	10.45	58.38	31.01	20.53	9.81	9.52	9.33	194.40	2491.56	16.85
1956	10.95	10.69	10.50	15.94	13.03	9.94	9.75	9.57	9.38	297.58	22.83	9.67
1957	9.48	9.30	9.15	54.36	21.75	35.12	14.92	10.13	8.25	38.83	49.52	7.84
1958	24.60	7.58	11.33	7.32	27.32	73.03	25.13	7.06	14.70	63.80	37.04	27.82
1959	15.80	19.35	6.64	6.50	16.96	6.35	6.20	6.09	6.09	77.28	37.61	10.82
1960	24.68	37.37	42.09	99.26	47.73	42.42	22.94	7.73	7.51	34.41	128.53	23.20
1961	38.65	9.04	14.81	24.81	10.83	8.42	8.20	8.05	13.08	40.13	101.17	33.88
1962	51.73	13.63	59.79	64.23	42.00	51.08	24.80	8.41	8.15	31.74	15.68	23.73
1963	9.47	9.87	30.07	25.76	29.39	12.93	9.21	6.82	6.67	54.01	94.06	32.47
1964	12.18	35.92	17.98	17.77	13.86	15.47	8.62	6.74	7.18	55.33	55.80	318.43
1965	41.19	41.37	31.07	24.29	28.30	23.06	17.14	9.64	9.46	49.74	30.85	40.03
1966	8.87	401.34	4063.99	1410.05	2299.58	66.91	36.21	15.65	10.69	89.11	173.75	61.17
1967	15.26	18.30	18.54	10.49	10.34	10.15	10.26	13.92	16.09	52.65	48.27	22.32

EVAP	2.65	3.10	4.71	5.50	6.65	9.32	6.16	3.32	3.22	3.73	2.46	2.31	53.12
PE	0.43	0.60	0.98	1.26	0.71	0.43	3.79	3.77	2.17	0.98	0.50	0.46	16.10

RED ROCK RESEVOIR FILLING STARTING WITH EMPTY RESERVOIR

AVERAGE MONTHLY DATA - YEARS 1939-1967, AND 1936-1938

MONTHS

	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VOLUME	2258.90	2262.36	2254.26	2233.77	2194.16	2131.49	2247.91	2304.95	2321.27	2310.36	2317.19	2333.49	2264.18
EVAP	18.91	22.97	33.47	39.09	47.60	69.35	45.06	24.61	24.37	27.51	18.49	17.40	388.84
PE	2.98	4.21	6.69	9.18	5.13	2.76	28.49	27.54	15.74	7.25	3.78	3.17	116.92
EVAP-PE	15.93	18.75	26.79	29.91	42.47	66.59	16.57	-2.93	8.64	20.26	14.71	14.23	271.91
SEEPAGE	5.31	5.35	5.36	5.35	5.33	5.29	5.34	5.41	5.45	5.45	5.45	5.47	64.56

FIRST SPILL OCCURED 187 MONTHS AFTER START OF FILL.

AVE. VOLUME OF SPILL = 643.6721 AC.FT.

16 SPILLS OCCURED.

RESERVOIR WAS EMPTY 0 TIMES.

RED ROCK RESEVOIR FILLING STARTING WITH FULL RESERVOIR

AVERAGE MONTHLY DATA - YEARS 1939-1967, AND 1936-1938

MONTHS

	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
VOLUME	3093.94	3091.60	3074.91	3044.71	2992.84	2914.69	3001.24	3050.42	3063.34	3046.73	3049.46	3062.18	3040.51
EVAP	24.59	28.91	43.65	50.56	60.63	85.16	55.65	30.16	29.60	34.14	22.74	21.34	487.12
PE	4.04	5.50	9.05	11.72	6.70	3.94	34.49	34.28	19.92	8.91	4.60	4.19	147.33
EVAP-PE	20.55	23.41	34.60	38.85	53.93	81.22	21.16	-4.12	9.67	25.23	18.13	17.15	339.80
SEEPAGE	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	73.56

FIRST SPILL OCCURED 0 MONTHS AFTER START OF FILL.

AVE. VOLUME OF SPILL = 497.3257 AC.FT.

23 SPILLS OCCURED.

RESERVOIR WAS EMPTY 0 TIMES.

Table 2. Summary of Reservoir Filling Analysis over 32-Year Period

Months to Fill			Volume in Storage (AF)			Surface Area (acres)			Number of Spills After Filled			Ave Volume of Spill (AF)			Ave Volume of Spill per Year (AF/yr)	Net Evaporation Losses (AF/yr)			Seepage Losses (AF/yr)		
Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max		Min	Ave	Max	Min	Ave	Max
1	104	235	2828	2914	3065	102	105	109	21	24	34	345	487	549	365	323	330	341	73.6	73.6	73.6

Table 3. Simulated Mean Monthly Flow (AF) From Treatable Areas Before Treatment - Drainages above Patagonia and Bird Sanctuary

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1936	12.83	13.90	9.63	1.09	0.00	0.00	0.00	4.81	5.88	0.00	5.33	10.67	64.14
1937	10.67	16.55	19.75	8.56	0.00	0.00	0.00	0.00	0.00	0.00	4.27	10.67	70.47
1938	12.28	13.35	13.35	6.24	0.00	0.00	0.00	0.45	0.00	0.00	0.00	6.22	51.89
1939	8.00	12.01	9.34	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	30.71
1940	1.34	14.23	10.23	3.12	0.00	0.00	0.00	0.00	0.00	0.00	1.77	12.44	43.13
1941	19.12	21.79	19.13	18.69	6.70	0.00	0.00	0.00	0.00	0.00	0.00	9.34	94.77
1942	11.12	15.10	12.01	12.90	0.45	0.00	0.00	0.00	0.00	0.00	0.00	1.77	53.35
1943	3.55	1.34	0.00	0.00	0.00	0.00	0.00	9.80	0.91	0.00	0.00	4.43	20.03
1944	7.56	11.12	12.47	7.56	0.00	0.00	0.00	0.00	0.00	0.00	4.43	9.77	52.91
1945	12.90	11.12	12.90	7.13	0.00	0.00	0.00	7.56	0.00	1.34	0.00	0.00	52.95
1946	8.89	7.10	4.89	0.00	0.00	0.00	7.13	25.64	8.91	7.13	7.13	7.59	84.41
1947	8.47	7.59	4.03	0.00	0.00	0.00	0.00	11.12	0.45	0.00	1.34	3.55	36.55
1948	2.23	8.46	9.34	0.45	0.00	0.00	0.00	6.67	3.12	0.00	0.00	6.22	36.49
1949	12.29	19.58	15.56	7.13	0.00	0.00	0.00	0.00	0.00	1.34	0.00	7.56	63.46
1950	8.46	9.34	4.90	0	0	0	194.49	1.32	0	0	0	0	218.51
1951	5.79	4.90	2.23	6.24	0	0	0.45	8.91	9.76	9.32	2.23	10.23	60.06
1952	13.34	13.79	23.14	24.02	12.04	0	0	0	0	0	5.34	12.01	103.68
1953	9.77	14.68	13.79	6.24	0	0	0	0	0	0	4.44	3.98	52.90
1954	3.55	0.88	6.67	0	0	0	0	21.02	14.68	8.91	5.35	4.47	65.53
1955	12.04	12.04	8.47	1.37	0	0	9.34	268.94	4.88	2.21	0	0	319.29
1956	0.88	1.34	0	0	0	0	12.90	11.58	0	0	0	0.45	27.15
1957	10.67	7.56	8.46	1.80	0	0	0	3.12	0	0.45	0	0.45	32.51
1958	0	4.44	15.57	9.34	0	0.45	8.47	9.37	7.16	3.60	4.49	2.71	65.60
1959	1.37	5.81	2.52	0	0	0	6.74	12.92	0.91	2.68	5.35	11.14	49.44
1960	20.30	20.30	14.44	6.98	0	0	0	0.55	0	0	0	1.07	63.64
1961	4.27	3.20	0	0	0	0	0	0.55	0	5.34	4.82	13.35	31.53
1962	20.82	17.62	9.36	10.15	0	0	0	0	0	0	0	5.34	63.29
1963	6.40	8.02	4.82	0	0	0	3.75	6.98	1.09	0	5.34	6.40	42.80
1964	6.95	5.88	5.88	0	0	0	15.05	11.22	25.25	15.48	15.48	14.44	115.63
1965	13.38	14.44	12.31	4.84	0	0	0	0	0	0	58.27	503.16	606.40
1966	102.49	128.09	26.13	17.04	3.20	0	0	4.81	6.43	0	0	0	288.19
1967	0	0	0	0	0	0	0	0	0	0.55	0	21.34	21.89
													2,983.30

Table 4. Simulated Mean Monthly Flow (AF) From Treatable Areas Following Treatment - Drainages Above Patagonia and Bird Sanctuary

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1936	8.14	19.21	14.94	5.33	3.72	3.20	3.20	9.08	10.67	3.72	9.60	15.48	106.29
1937	14.94	20.44	25.09	13.35	4.27	3.75	3.75	3.20	3.20	3.20	7.47	15.48	118.14
1938	16.00	16.55	17.62	10.68	2.23	2.23	1.77	3.12	1.77	1.77	1.77	8.00	83.51
1939	10.23	14.67	12.01	3.10	0.88	0.88	0.88	1.34	1.34	0.88	0.88	1.34	48.43
1940	3.12	16.46	12.01	5.35	0.88	0.88	0.88	1.34	0.88	0.88	2.67	13.79	59.14
1941	20.90	24.46	21.79	21.35	9.80	3.55	3.12	3.12	3.12	3.12	2.67	12.89	129.89
1942	14.67	18.69	15.56	16.91	4.03	1.77	1.77	1.77	1.77	1.77	1.34	3.55	83.60
1943	5.33	3.12	0.88	0.88	0.88	0.88	0.88	12.01	5.33	5.33	4.89	9.34	49.75
1944	12.43	16.46	18.23	13.35	3.55	3.55	3.55	3.12	2.67	2.67	8.00	13.33	100.91
1945	16.46	9.47	16.46	10.68	1.77	1.77	1.77	10.23	5.33	7.10	4.43	4.43	89.90
1946	14.22	12.01	9.34	3.55	3.55	3.55	11.57	105.86	11.10	9.76	10.64	11.10	206.25
1947	11.98	11.10	7.97	7.09	7.09	6.19	6.19	54.53	10.19	9.76	11.07	13.30	156.46
1948	11.53	17.76	18.21	8.89	7.09	6.19	6.19	13.34	10.23	6.65	6.65	12.88	125.61
1949	18.48	26.67	22.67	13.79	4.87	4.87	4.43	4.43	3.98	5.33	3.55	11.55	124.62
1950	12.44	13.34	9.34	2.67	2.67	2.67	276.68	10.19	9.76	9.30	8.86	8.41	366.33
1951	14.20	13.31	10.64	14.65	6.20	6.20	7.54	30.13	9.76	9.32	11.53	19.54	153.02
1952	22.66	22.22	43.40	120.87	15.98	9.76	9.30	8.86	8.41	7.97	13.31	19.99	302.73
1953	17.32	21.77	21.34	13.34	13.34	5.31	5.31	4.88	4.88	3.98	4.44	3.98	119.89
1954	7.54	5.34	11.56	3.10	3.10	3.10	2.67	77.85	16.44	10.67	9.30	8.86	159.53
1955	16.87	16.87	12.88	7.09	7.09	6.20	42.95	410.58	10.19	9.76	9.30	8.86	558.64
1956	9.76	9.32	7.52	7.09	7.09	6.20	84.08	13.77	9.77	9.30	8.86	8.86	181.62
1957	19.54	16.44	17.32	10.21	6.20	6.20	5.77	9.32	5.31	5.77	5.34	5.34	112.76
1958	4.44	9.77	20.90	15.11	3.10	4.44	36.15	14.22	12.01	9.77	10.67	8.43	149.01
1959	7.54	12.42	8.43	6.83	6.20	5.77	49.74	58.56	10.19	11.97	15.09	20.43	213.17
1960	30.40	29.33	23.47	16.00	6.92	5.86	5.86	7.47	5.34	5.34	5.34	6.40	147.73
1961	9.60	8.54	4.82	3.72	3.72	3.20	3.20	5.34	2.65	8.54	8.02	17.62	78.97
1962	25.09	21.89	25.09	15.48	4.27	3.75	3.75	3.75	3.20	2.68	2.68	8.54	120.17
1963	10.67	11.22	8.56	2.68	1.61	1.61	6.95	11.76	5.88	5.34	12.28	13.35	91.91
1964	13.35	11.76	11.22	5.88	4.27	3.75	97.83	13.32	48.56	17.04	17.59	16.52	261.09
1965	16.00	16.52	14.94	7.99	6.38	6.38	5.86	5.86	5.34	4.79	190.25	529.29	809.60
1966	111.02	136.63	26.13	31.90	9.03	8.51	7.96	13.32	16.00	8.54	7.99	8.54	385.57
1967	6.92	6.40	5.85	5.33	5.33	5.31	5.88	4.79	5.33	5.33	4.27	26.67	87.41
													5,781.65

NO. 7

FLOOD DESIGN

FOR

RED ROCK CANYON

Summary and Conclusions:

A 3.5 in.-1 hr. storm can be expected on some part of this watershed once every 10 yrs. or less.

Individual exceptional storms produce as much surface runoff as several years of normal runoff. Such storms also provide the unusual peak discharges and storm volumes needed for flood design purposes.

Storm runoff per unit area decreases with increasing watershed site because of the limited areal extent of runoff-producing thunderstorms as well as transmission loss in the streambeds.

A peak discharge of 1500 cfs per square mile probably occurs on some small part of the principal watershed several times in 10 years. However, such an event on a specific small subwatershed would be expected less than once in 10 years, and probably closer to once in 50 years. Runoff from these small areas could produce 137 ac-ft sq-mile.

The 4.5 in. 6 hr. storm is the minimum acceptable design storm for this area for dam design purposes.

DESIGN STORM

FOR

RED ROCK CANYON

Design storm data for Red Rock was obtained from U. S. Weather Bureau TP #40 using a 6 hr. 100 yr. design storm of 4.5 inches. Additional information was used from the ARS watersheds at Walnut Gulch, Arizona, for two storms in 1964 and 1967. This information is included at the end of this section.

The 1964 design storm of 3.5 inches was applied to the 28 sq. mi. watershed using an areal adjustment factor of 0.8 inches, which brings the areal precipitation down to 2.6 inches. This storm was used, as the research data from Walnut Gulch W. S. showed that a storm of this magnitude could be expected with a return period of 10 years or less. This same storm of 3.5 inches of precipitation over a 45 minute time period produced 1500 csm from an 84 acre watershed at Walnut Gulch.

The peak runoff from this hydrograph was 2561 cfs or 92 CSM from the 28 sq. mi. area.

Channel measurements taken at the dam Site "A" by F. Brown and D. Anderson showed that a peak discharge of 3860 cfs had passed through the area from visible evidence of high water which was still present.

A design storm of 4.5 inches for a 6 hr. storm was plotted giving a peak discharge of 5050 cfs from the 28 sq. mi. area, which is 180 CSM. A storm of this magnitude can be expected with a return of 100 years.

The total volume under the hydrographs of these two storms is 1058 ac. ft. for the 3.5 in. 45 min. storm, and 2166 ac. ft. for the 4.5 in. 6 hr. storm.

A runoff curve of 75 was used on the 28 sq. mi. area. This curve was derived from the slope, vegetative cover density, and a hydrologic soil group "D". The runoff (Q) from this curve No. 75 was 0.7 inches for the 3.5 in. storm, and 1.7 in. for the 4.5 in. storm. Checking these results from Walnut Gulch on the 1964 storm (3.5 inches) and for 28 sq. miles showed that 0.7 inches of runoff could be expected. The runoff curve of 75 was applied to Parker Canyon in 1961 (Brown) and proved to be about right for this general area due to similar vegetation and soils.

HYDROGRAPH COMPUTATION

Exhibit 1

WATERSHED OR PROJECT Red Rock Canyon STATE Arizona

STRUCTURE SITE OR SUBAREA Patagonia R. D., Coronado N. F.

DR. AREA 28 SQ. MI. T_c 2.0 HR. RUNOFF CONDITION NO. III

RUNOFF CURVE NO. 75 , STORM DISTRIB. CURVE A , HYDROGRAPH FAMILY NO. 2

STORM DURATION 1 HR. RAINFALL: POINT 3.5 IN. AREAL 2.6 IN.

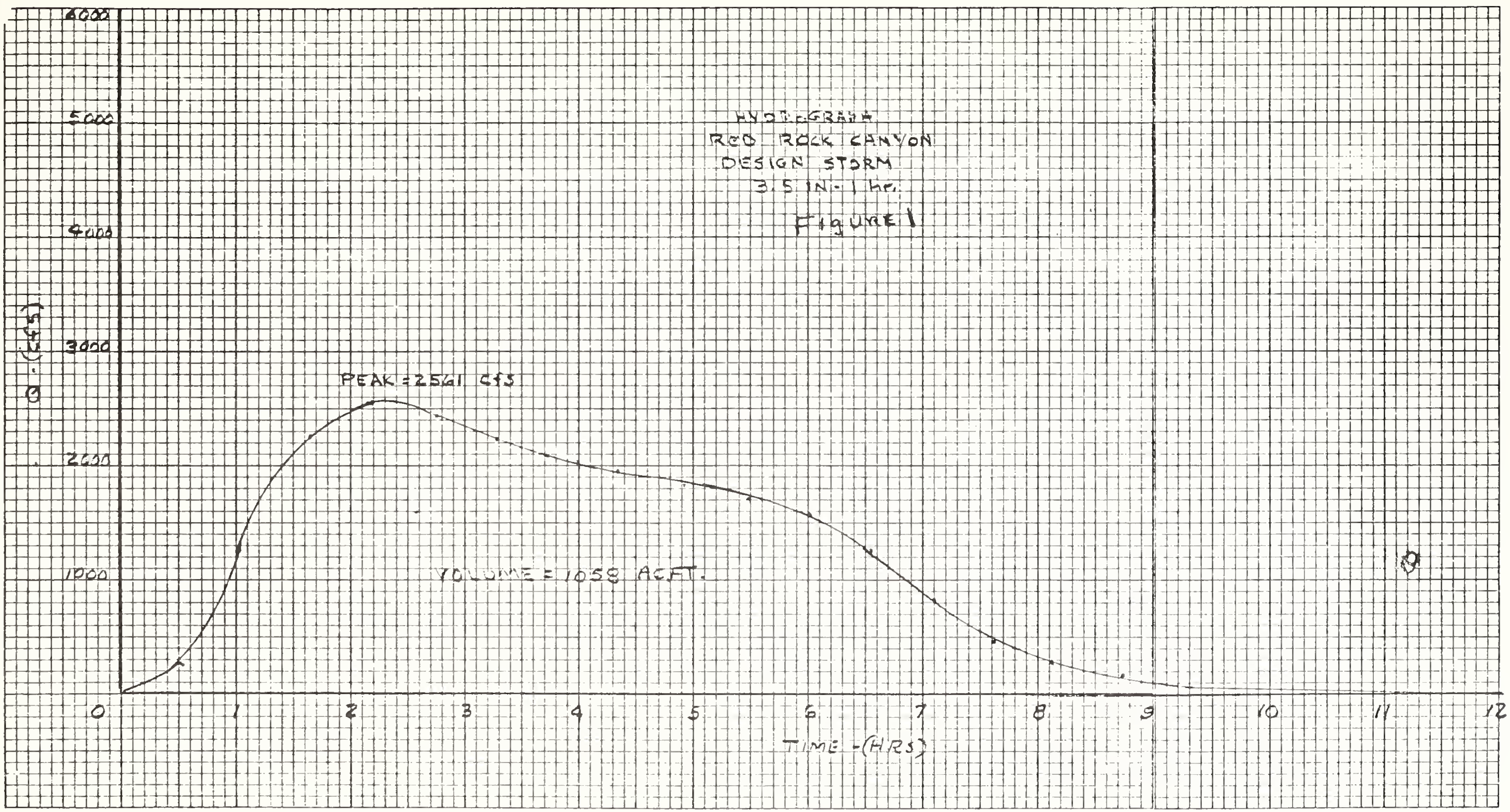
Q 0.7 IN. COMPUTED T_p 1.4 HR. T_o 5.6 HR.

$(T_o + T_p)$: COMPUTED 4 USED 4 . REVISED T_p 1.4

$q_p = \frac{484\ A}{\text{REV. } T_p} =$ 9680 CFS. Qq_p = 6776 CFS.

t(COLUMN) = (t/T_p) REV. T_p. q(COLUMN) = $(q_c/q_p)\ Qq_p$. CSM = 92

LINE NO.	t HOURS	q CFS	LINE NO.	t HOURS	q CFS	LINE NO.	t HOURS	q CFS
1	0	0	21	10.92	14	41		
2	.55	284.6	22	11.47	7	42		
3	1.09	1274	23	12.01	0	43		
4	1.64	2256	24			44		
5	2.18	2561	25			45		
6	2.73	2480	26			46		
7	3.28	2324	27			47		
8	3.82	2155	28			48		
9	4.37	1985	29			49		
10	4.91	1823	30			50		
11	5.46	1714	31			51		
12	6.01	1579	32			52		
13	6.55	1267	33			53		
14	7.10	806	34			54		
15	7.64	461	35			55		
16	8.19	264	36			56		
17	8.74	149	37			57		
18	9.28	81	38			58		
19	9.83	47	39			59		
20	10.37	27	40			60		


HYDROGRAPH
RED ROCK CANYON
DESIGN STORM
3.5 IN.-1 hr.
Figure 1
PEAK = 2561 cfs
VOLUME = 1058 AC.FT.
Q - (cfs)
6000
5000
4000
3000
2000
1000
0
1
2
3
4
5
6
7
8
9
10
11
12
TIME - (HRS)

12.91 D"

HYDROGRAPH COMPUTATION

Exhibit 2

WATERSHED OR PROJECT Red Rock Canyon STATE Arizona

STRUCTURE SITE OR SUBAREA Patagonia R. D., Coronado N. F.

DR. AREA 28 SQ. MI. T_c 2.0 HR. RUNOFF CONDITION NO. III

RUNOFF CURVE NO. 75 , STORM DISTRIB. CURVE A , HYDROGRAPH FAMILY NO. 2

STORM DURATION 6 HR. RAINFALL: POINT 4.5 IN. AREAL 3.6 IN.

Q 1.4 IN. COMPUTED T_p 1.4 HR. T_o 5.7 HR.

$(T_o \div T_p)$: COMPUTED 4.05 , USED 4.0 , REVISED T_p 1.42

$q_p = \frac{484\ A}{REV.\ T_p} =$ 9544 CFS. $Qq_p =$ 13,361 CFS.

t(COLUMN) = (t/T_p) REV. T_p. q(COLUMN) = (q_c/q_p) Qq_p. 180 CSM

LINE NO.	t HOURS	q CFS	LINE NO.	t HOURS	q CFS	LINE NO.	t HOURS	q CFS
1	0	0	21	11.08	27	41		
2	0.55	561	22	11.63	13	42		
3	1.11	2512	23	12.18	0	43		
4	1.66	4449	24			44		
5	2.22	5050	25			45		
6	2.77	4890	26			46		
7	3.32	4583	27			47		
8	3.88	4249	28			48		
9	4.43	3915	29			49		
10	4.98	3594	30			50		
11	5.54	3380	31			51		
12	6.09	3113	32			52		
13	6.64	2498	33			53		
14	7.20	1590	34			54		
15	7.75	909	35			55		
16	8.31	521	36			56		
17	8.86	294	37			57		
18	9.41	160	38			58		
19	9.97	94	39			59		
20	10.52	53	40			60		

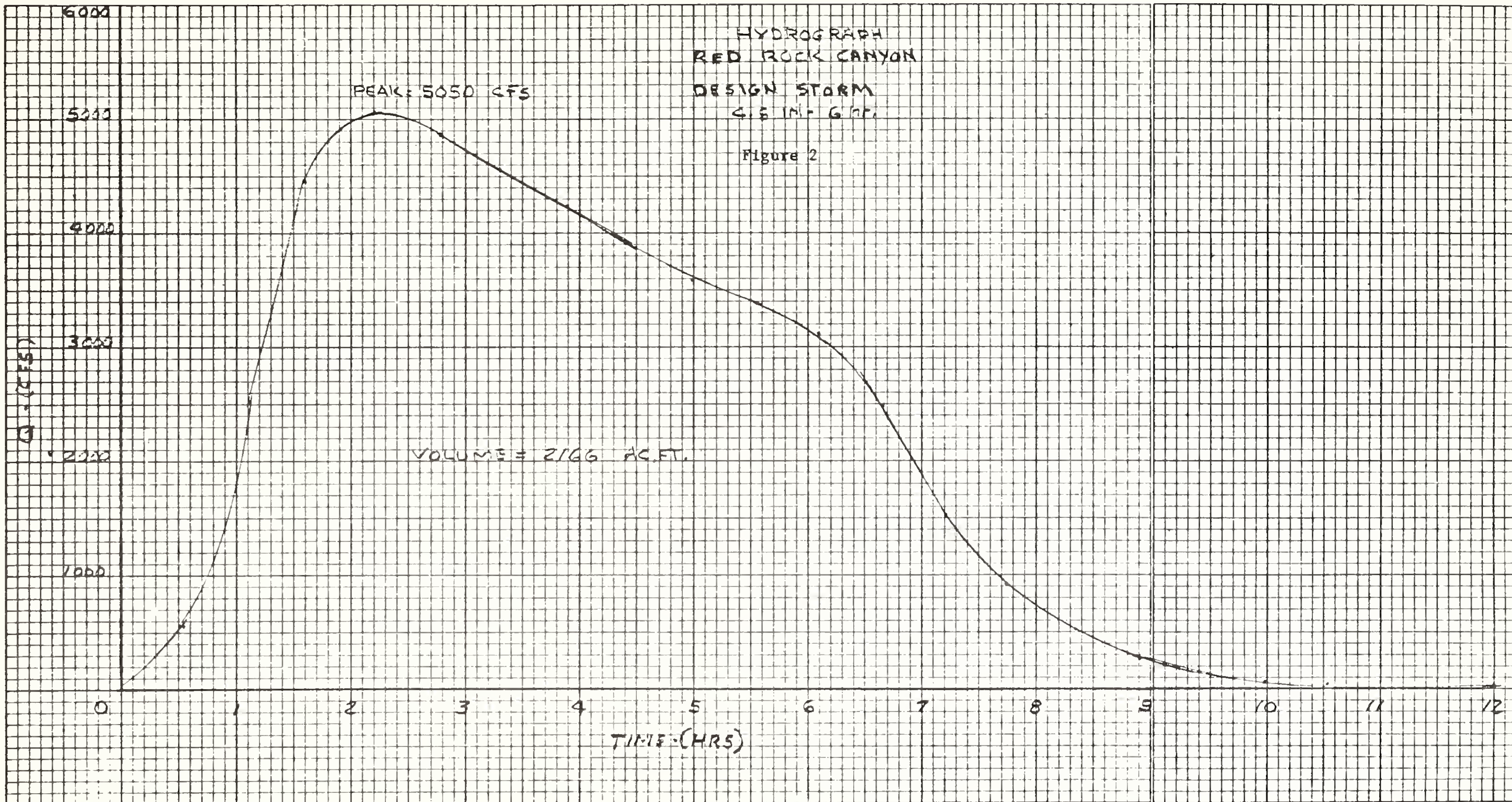


Figure 2

26.42 □'

3

CHANNEL MEASUREMENT NOTES

Stream Red Rock Canyon Date 1-30-69

Location & Length of Reach Upstream from Damsite "A", up from confluence from 1st drainage

WPU - Party Anderson & Bedell

Slope Energy Grad. 0.01 Roughness Coef 0.035

Peak Discharge 2495 cfs 113 CSM Channel Capacity -

Area 22 mi^2 Hydraulic Rad. 2.22 Velocity 9.4

STA-TION	DIST. FROM INIT PT(ft)	DEPTH (FEET)	DISCHARGE (cfs)	STA-TION	DIST. FROM INIT. PT(ft)	DEPTH (feet)	DISCHARGE (cfs)
	0				0		
1	6	3.9		7	65	3.8	
2	11	3.5		8	74	3.0	
3	19	3.3		9	77	0	
4	35	3.6					
5	41	3.7					
6	54	4.2					

NOTES: Bank full stage
Channel smooth
Bed material coarse texture to rock 6" dia.

Exhibit 3

CHANNEL MEASUREMENT NOTES

Stream Lampshire Canyon Date 1-30-69

Location & Length of Reach Confluence with Red Rock Canyon

WPU - Party Anderson, Bedell

Slope Energy Grad. 0.008 Roughness Coef 0.025

Peak Discharge 838 cfs 120 CSM Channel Capacity -

Area 7 mi^2 Hydraulic Rad. 1.0 Velocity 5.3

STA-TION	DIST. FROM INIT PT(ft)	DEPTH (FEET)	DISCHARGE (cfs)	STA-TION	DIST. FROM INIT. PT(ft)	DEPTH (feet)	DISCHARGE (cfs)
	0				0		
1	6	4.4					
2	9	5.0					
3	20	4.8					
4	25	4.9					
5	29	5.25					
6	41	0					

NOTES: Channel smooth - No vegt.
Peak flow marks at bank full stage
Bed rock in bed

1

CHANNEL MEASUREMENT NOTES

Stream Red Rock Canyon Date 1-30-69

Location & Length of Reach Next to Siebold Ranch

WPU - Party Brown & Anderson

Slope Energy Grad. 0.01 Roughness Coef 0.035

Peak Discharge 4535 cfs / 151 CSM Channel Capacity -

Area 30 mi^2 Hydraulic Rad. 2.2 Velocity 9.6

STATION	DIST. FROM INIT PT(ft) 0	DEPTH (FEET)	DISCHARGE (cfs)	STATION	DIST. FROM INIT. PT(ft) 0	DEPTH (feet)	DISCHARGE (cfs)
1	10	5.0		7	100	4.0	
2	25	5.0		8	137	0.0	
3	59	5.5					
4	66	2.0					
5	86	2.5					
6	95	4.0					

NOTES: 150' downstream from meander
Scattered grass & trees in channel
Smooth bed & banks

2

CHANNEL MEASUREMENT NOTES

Stream Red Rock Canyon Date 1-30-69

Location & Length of Reach 200 ft. downstream from Site "A"

WPU - Party Anderson & Bedell

Slope Energy Grad. 0.01 Roughness Coef 0.040

Peak Discharge 3860 cfs / 138 CSM Channel Capacity -

Area 28 mi^2 Hydraulic Rad. 2.47 Velocity 9.2

STATION	DIST. FROM INIT PT(ft) 0	DEPTH (FEET)	DISCHARGE (cfs)	STATION	DIST. FROM INIT. PT(ft) 0	DEPTH (feet)	DISCHARGE (cfs)
1	5.5	0.6		7	64	5.4	
2	11	2.5		8	71	4.7	
3	12	4.4		9	81	4.3	
4	27	4.8		10	93	4.0	
5	36	5.3		11	100	0.0	
6	50.0	5.3					

NOTES: Meander upstream
Vegt. sparse
Moderate bottom changes
Smooth bottom

Exhibit 4

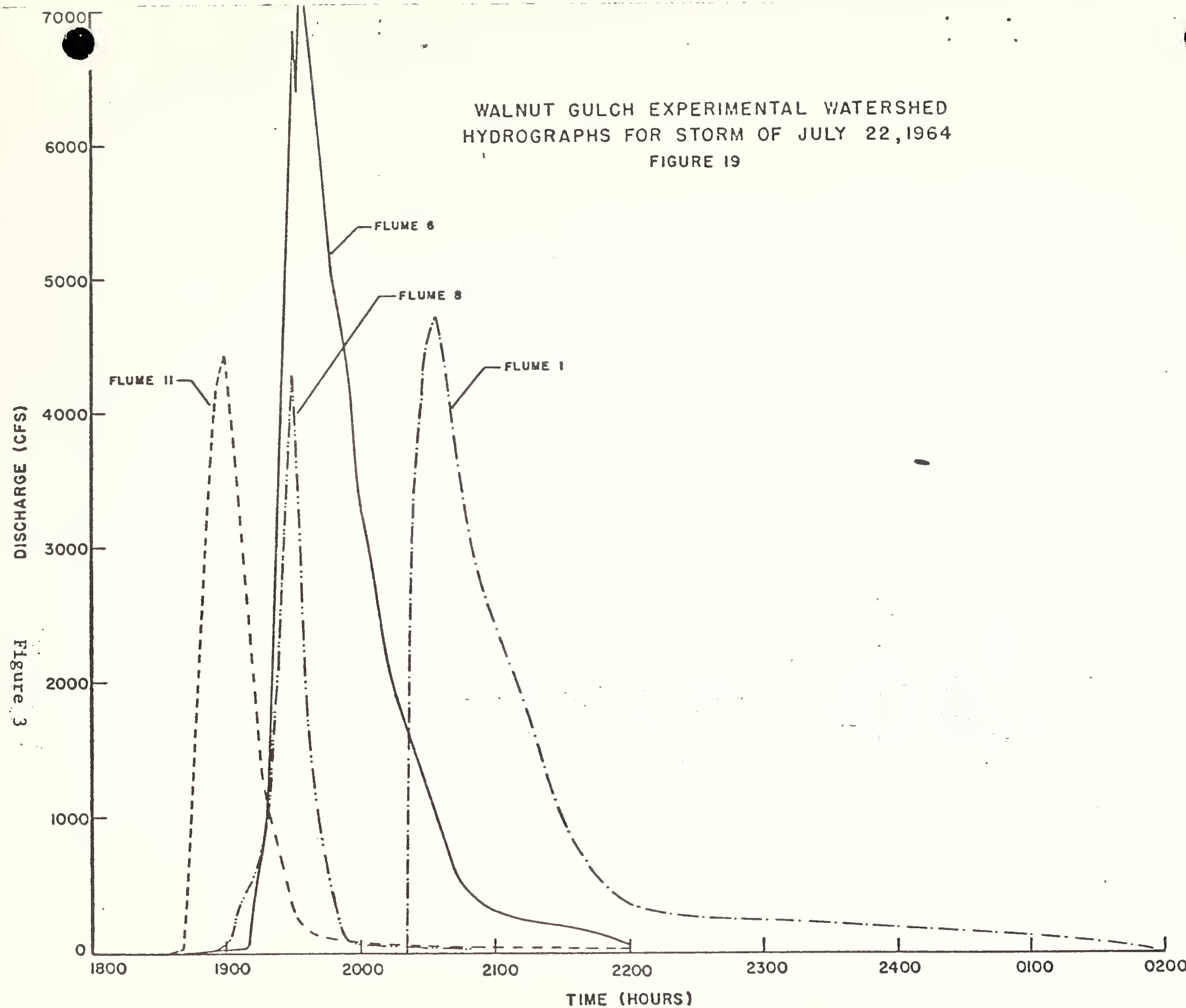

WALNUT GULCH EXPERIMENTAL WATERSHED
HYDROGRAPHS FOR STORM OF JULY 22, 1964
FIGURE 19
FLUME 6
FLUME 8
FLUME 11
FLUME 1
DISCHARGE (CFS)
7000
6000
5000
4000
3000
2000
1000
0
1800
1900
2000
2100
2200
2300
2400
0100
0200
TIME (HOURS)

Figure 3

WALNUT GULCH EXPERIMENTAL WATERSHED
HYDROGRAPHS FOR STORM OF SEPT. 10, 1967
FIGURE 18

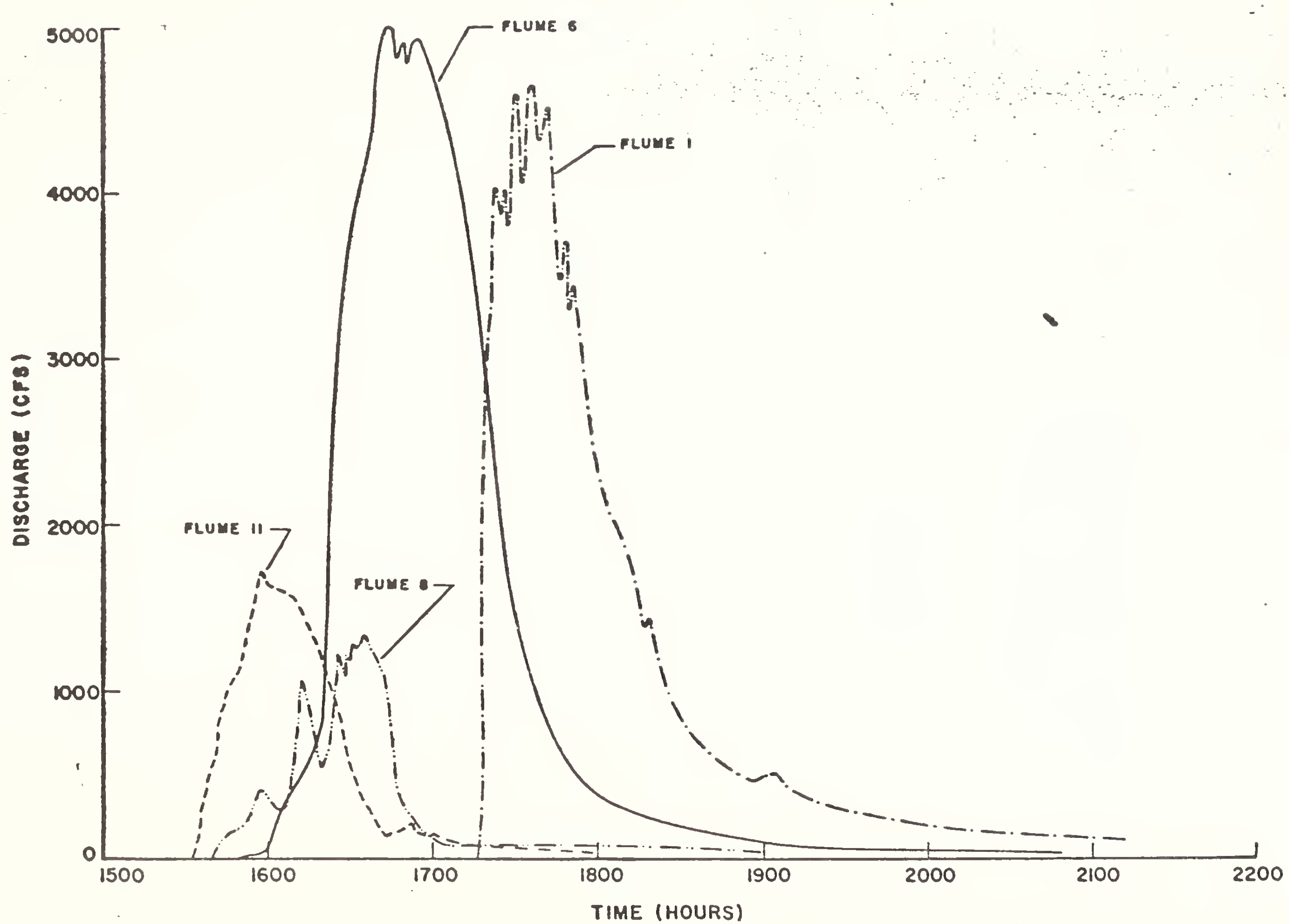


Figure 4

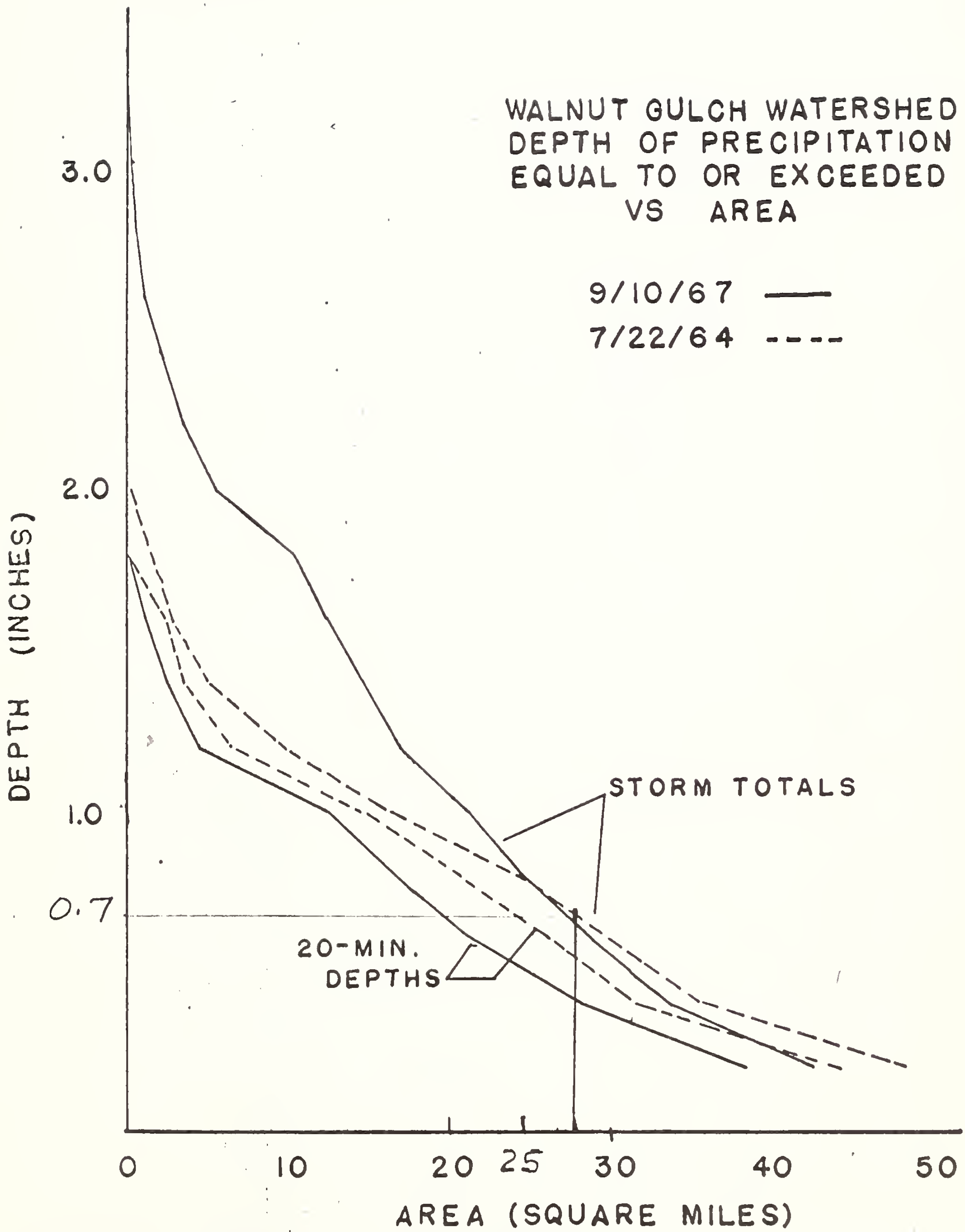

WALNUT GULCH WATERSHED
DEPTH OF PRECIPITATION
EQUAL TO OR EXCEEDED
VS AREA
9/10/67
7/22/64
3.0
2.0
1.0
0.7
DEPTH (INCHES)
STORM TOTALS
20-MIN.
DEPTHS
0
10
20
25
30
40
50
AREA (SQUARE MILES)

FIGURE 5

VOLUME OF PRECIPITATION ABOVE ISOHYET DEPTHS
FOR STORMS OF SEPT. 10, 1967 AND JULY 22, 1964
FIGURE 20

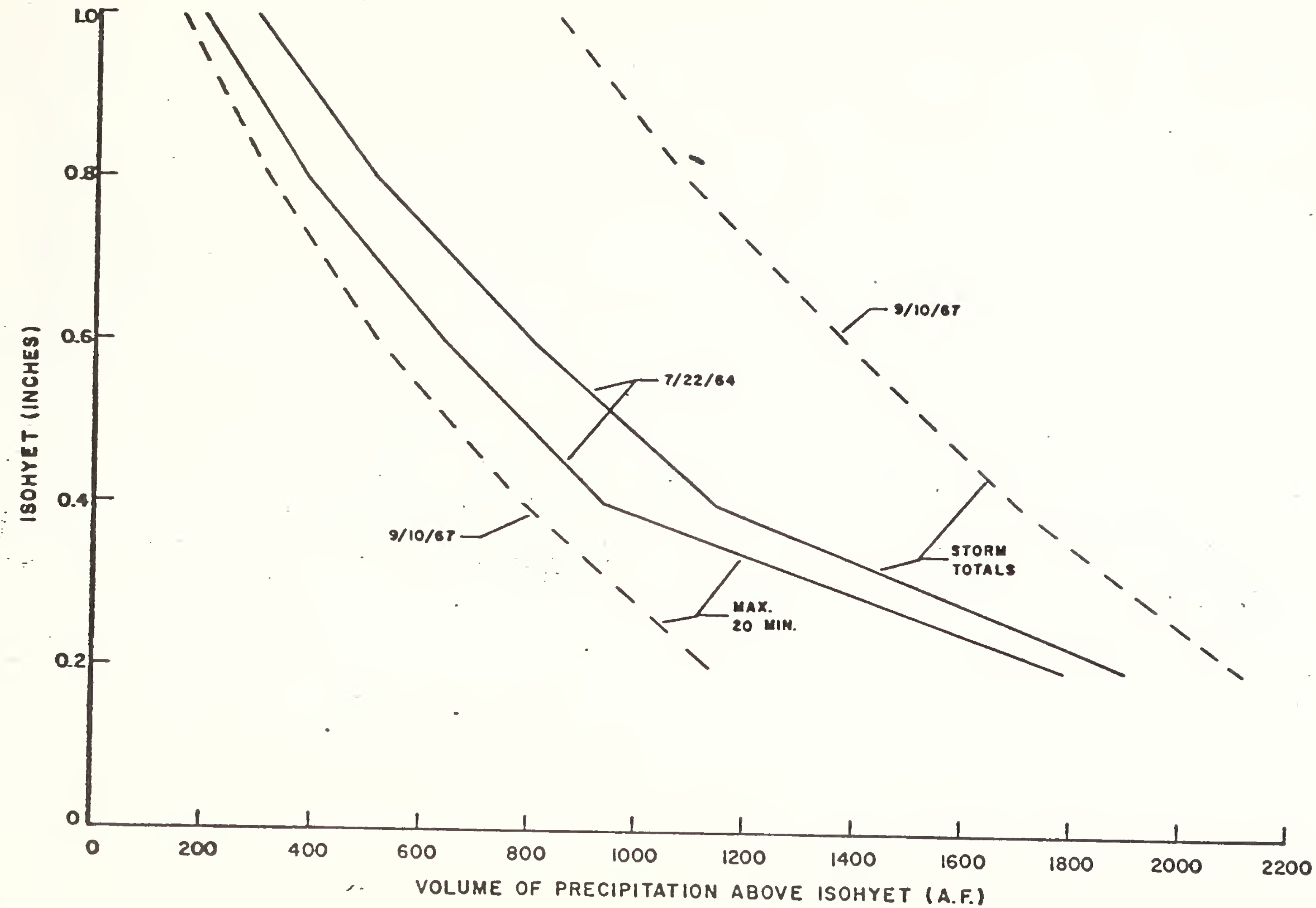


Figure 6

WALNUT GULCH EXPERIMENTAL WATERSHED
DISCHARGE VERSUS AREA
FIGURE 21

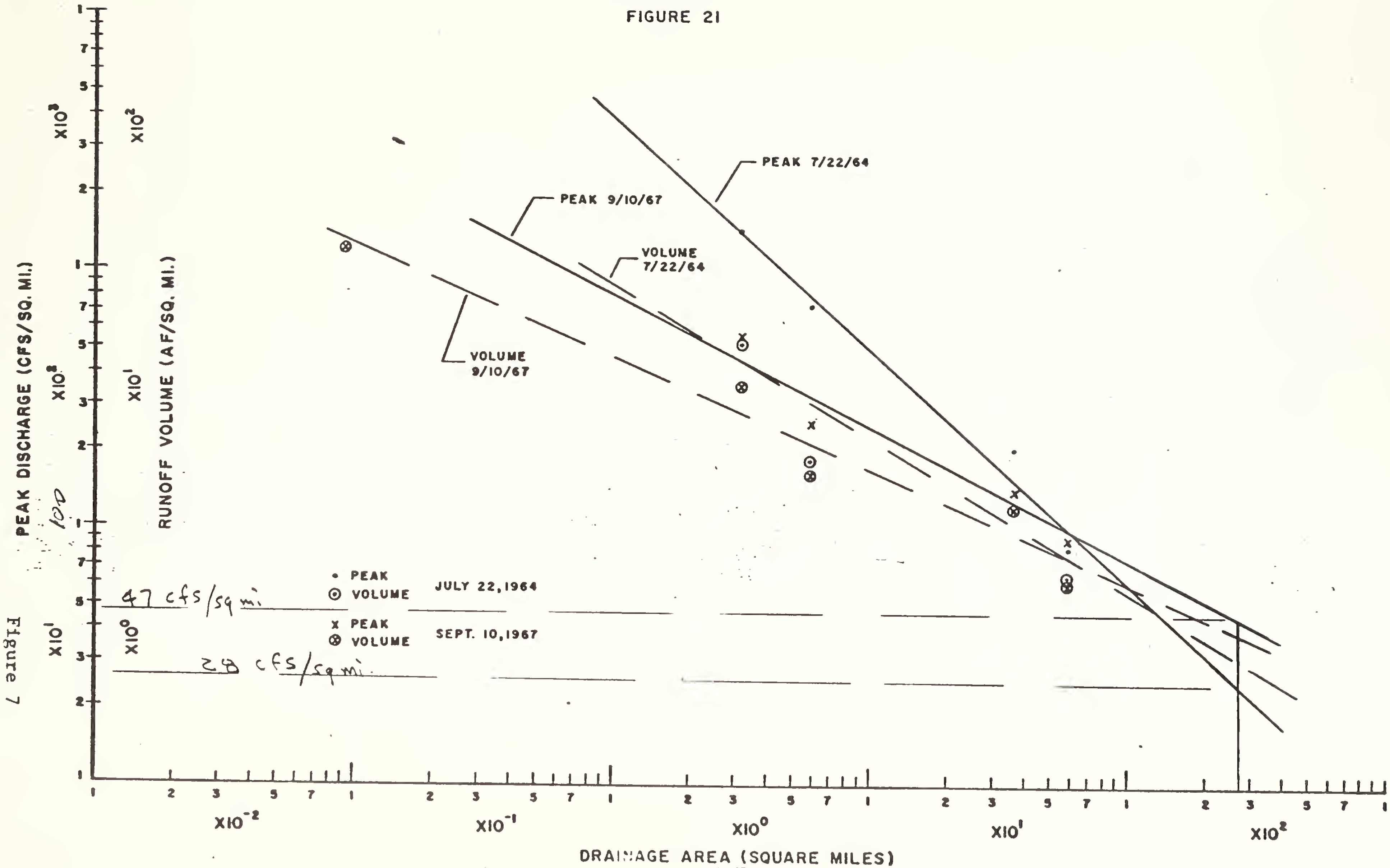


Figure 7

NO. 8

SEDIMENT YIELD

Summary and Conclusions:

Total sediment yield from Red Rock Canyon above damsite "A" is 7.24 AF per year, or 0.26 AF per sq mi/yr, which is considered in the low to moderate level for the Pacific Southwest.* About 56 percent of the sediment yield comes from sheet erosion. From the sediment yield calculations, a dam of 125 surface acres at Site "A" will lose 10 percent of its storage capacity over a 50 year period.

Total sediment yield from the treatable areas in the Patagonia and Santa Rita Mountains is at present 0.97 AF per year or 0.19 AF per sq. mi per year. Approximately 25 percent of the total sediment yield comes from sheet erosion. Conversion to a grass cover will result in an increase in sheet erosion of 0.05 AF per year. However, through the conversion program, maintenance of existing roads will enable a net reduction in total sediment yield of 0.13 AF per year.

* Pacific Southwest Inter-Agency Committee, 1968. Factors Affecting Sediment Yield and Measures for the Reduction of Erosion and Sediment Yield.

Sediment Computations

Sediment yield from the Red Rock Watershed was computed using the following equations for sheet and mass erosion:

Sheet erosion by a modified Musgraves equation

$$E_S = IR\left(\frac{S^{1.35}}{100}\right) L^{0.35}\left(\frac{P_{30}}{1.375}\right)^{1.75}$$

Where:

E_S = Sheet erosion in inches

I = Basic erosion rate (in/yr)

R = Cover factor

S = Slope (percent)

L = Slope length (ft)

P_{30} = 2,yr, 30 minute precipitation intensity (in/hr)

Mass Erosion

$$E_m = 0.000189\, XDA$$

Where:

E_m = Mass erosion (AF/yr)

X = Ave. change in cross-sectional area (ft^2/yr)

D = Density of roads or gullies (mi/mi^2)

A = Area in acres

Table 1. Sediment Yield from Sheet Erosion for Red Rock Canyon Watershed

Sub-watershed	Basic Erosion Rate (in/yr)	Ave. Slope (%)	Slope Factor	Precip. Factor	Cover Density (%)	Cover Factor	Area (Acres)	Sheet Erosion AF/yr
1	0.15	33	4.11	0.572	80	0.008	1768	0.42
2	0.17	33	4.11	0.572	85	0.007	2635	0.61
3	0.20	19	2.50	0.572	92	0.006	1577	0.22
4	0.18	39	5.40	0.572	90	0.006	3843	1.05
5	0.14	22	2.65	0.572	88	0.007	618	0.08
6	0.11	37	4.75	0.572	88	0.007	2004	0.35
7	0.15	36	4.60	0.572	80	0.008	3429	0.90
8	0.17	26	3.45	0.572	75	0.009	1956	0.49
						Total	17,820	4.12

Table 2. Sediment Yield from Mass Erosion for Red Rock Canyon Watershed

Subwatershed	X	D	A		Mass Erosion (AF/yr)
Gully Erosion					
1	0.80	0.80	1,768		0.21
2	0.80	0.50	2,635		0.19
3	0.73	0.60	1,577		0.13
4	0.38	0.95	2,843		0.20
5	0.30	0.70	618		0.02
6	0.30	0.65	2,004		0.08
7	0.42	0.60	3,429		0.16
8	0.37	0.45	1,956		0.06
Road and Trail Erosion					
	0.80	0.76	17,820		2.05
				TOTAL	3.12

Table 3. Sediment Yield from Sheet Erosion for Treatable Areas

HRU	Basic Erosion Rate (in/yr)	Avge. Slope (%)	Slope Factor	Precip. Factor	Cover Factor Before Treat.	Cover Factor After Treat	Area (Acres)	Sheet Erosion Before Treat. (AF/Yr)	Sheet Erosion After Treat. (AF/Yr)	Change in Sheet Erosion* (AF/Yr)
A1	0.05	30	3.879	0.572	0.008	.009	520	0.037	0.042	+0.005
A2	0.05	30	3.879	0.572	0.007	.008	547	0.036	0.040	+0.004
A3	0.08	30	3.879	0.572	0.007	.008	622	0.064	0.073	+0.009
A4	0.05	35	4.300	0.572	0.007	.009	1,535	0.109	0.141	+0.032
						Total	3,224	0.246	0.296	+0.050

* Denotes an increase in sediment yield.

Table 4. Sediment Yield from Mass Erosion for Treatable Areas

HRU	X	D	A	Mass Erosion (AF/Yr)	Potential Reduction* (AF/Yr)
Gullies and Tallus Slopes					
A1	0.50	0.30	520	0.015	0.003
A2	0.20	0.25	547	0.005	0.001
A3	0.40	0.45	622	0.002	0.000
A4	0.35	0.30	1535	0.030	0.007
Road and Trail					
A1	0.80	4.20	520	0.330	0.082
A2	0.80	0.01	547	0.001	0.000
A3	0.80	3.10	622	0.242	0.073
A4	0.80	0.20	1535	0.046	0.011
			Total	0.721	0.177

* Based on a 25% reduction following gully control and road improvement.

NO. 9

WATER QUALITY

FOR

SONOITA CREEK

Summary and Conclusions:

Chemical analysis of water in Sonoita Creek Basin shows that the water is of calcium bicarbonate, sulphate type, hard and of moderate to high dissolved solids content. The source of most of the dissolved solids in groundwater of the basin is the minerals of the weathered rocks material of the surrounding rocks.

Hardness is an undesirable characteristic of water used for domestic purposes. The water of the basin is very hard, exceeding 144 ppm, and reaches as high as 800 ppm.

WATER QUALITY

SAMPLE

Location:	100 ft. downstream from U.S.G.S. Sonoita Creek Gage
Date, Time:	2-8-1969, 10:55 a.m.
Temperature:	56°F
pH:	8.5
Total Alkalinity:	225 ppm
Hardness:	498 ppm
Free Acidity:	0
Total Acidity:	27.5 ppm
Carbon Dioxide:	30 ppm
Dissolved Solids:	540 ppm
Dissolved Oxygen:	10 ppm

No. 10

Hydrometeorological Tables

Table 1. Mean Monthly Discharge (cfs) for Sonoita Creek Gage near Patagonia

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Mean for Year
1936	6.6	8.3	10.1	7.8	8.0	6.2	4.7	2.8	1.9	16.2	31.9	4.5	9.1
1937	4.1	3.7	5.2	6.5	8.5	5.7	3.7	1.9	1.0	9.1	12.2	20.9	6.9
1938	3.6	4.0	4.3	4.3	5.2	4.1	2.6	1.9	.75	5.15	9.3	9.75	4.57
1939	1.08	2.3	2.5	3.0	3.3	3.0	2.3	1.0	.41	4.15	42.6	13.4	6.64
1940	1.61	2.8	3.1	3.4	6.0	3.0	.83	.39	.38	11.9	15.3	3.97	4.41
1941	1.10	1.8	12.1	14.9	28.2	7.1	2.49	1.22	.59	.96	12.7	3.4	7.10
1942	4.0	4.5	7.3	3.3	3.1	2.7	3.1	1.30	.40	1.24	3.91	4.15	3.25
1943	.64	1.3	2.0	2.1	2.2	2.1	1.46	.24	1.08	15.4	40.1	7.4	6.41
1944	.76	1.48	1.92	1.72	2.36	2.55	2.65	1.02	.24	.06	7.38	.20	1.87
1945	.45	1.72	3.40	4.72	4.26	3.47	2.78	1.05	.26	12.7	37.0	4.22	6.40
1946	9.60	1.90	2.72	3.80	3.11	3.13	1.57	.40	.04	13.5	23.5	48.0	9.29
1947	4.32	2.75	3.65	3.74	4.35	4.28	2.74	1.77	.73	5.80	8.79	5.02	4.01
1948	1.79	1.31	1.58	1.70	1.90	1.85	.90	.22	0.0	4.70	51.3	1.21	5.78
1949	.57	.84	1.53	4.93	7.65	3.55	3.03	1.20	.13	8.88	35.2	15.5	6.93
1950	2.59	2.27	2.79	3.04	3.25	3.21	2.00	1.11	.06	112.0	11.3	1.63	12.3
1951	1.19	2.10	3.72	5.02	4.98	5.52	5.14	2.62	.65	1.23	26.0	5.80	5.35
1952	3.87	1.71	2.68	4.42	4.40	8.76	5.82	2.28	.40	4.38	21.4	1.85	5.20
1953	2.38	4.03	5.71	5.02	4.87	4.50	2.91	1.25	.18	24.3	1.55	.23	4.78
1954	.03	.32	.99	1.11	.99	.87	.49	.06	0.0	45.1	59.0	11.1	10.2
1955	3.26	2.99	3.00	3.94	3.05	3.69	3.00	2.10	.44	24.6	151.0	12.0	18.0
1956	4.39	4.90	7.36	9.03	9.57	8.38	6.86	3.68	2.66	6.63	3.23	.55	5.60
1957	1.69	3.37	2.44	2.77	2.23	1.99	1.07	.40	.01	3.80	16.4	.05	3.05
1958	.06	1.14	1.92	2.48	2.54	10.1	2.41	.14	1.16	20.0	10.3	2.57	4.62
1959	3.02	2.07	4.75	4.32	4.11	3.87	3.40	2.18	2.17	10.6	29.7	3.81	6.22
1960	1.74	3.94	8.53	52.2	6.42	4.99	4.06	2.40	1.27	4.26	13.3	3.37	8.95
1961	14.9	5.17	6.18	5.86	4.86	4.86	3.51	1.44	.39	3.87	4.57	4.96	5.07
1962	2.01	.86	17.4	21.5	6.20	5.39	4.60	3.48	2.95	3.26	2.57	3.65	6.19
1963	3.95	3.80	4.10	4.34	4.80	2.72	1.92	.44	.12	8.26	62.7	7.17	8.79
1964	2.83	3.70	3.80	3.88	4.16	4.59	3.46	2.25	.83	5.68	52.1	70.5	13.1
1965	5.79	5.67	5.59	5.96	5.96	6.95	6.49	5.85	4.07	4.23	3.25	6.55	5.53
1966	1.48	2.0	107.0	23.2	95.6	15.9	11.9	7.53	7.09	36.5	71.3	20.8	33.1
1967	19.5	17.6	16.8	16.9	14.7	12.5	12.1	10.3	8.6	16.3	16.7	6.60	14.1

Table 2. Mean Monthly Temperature for Canelo Station--Elevation 4985 ft.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean for Year
1935							79.4	72.5	67.2	60.7	49.6	42.9	
1936	43.2	45.7	50.4	57.2	65.0	73.0	74.7	71.9	65.3	61.8	48.4	38.8	58.0
1937	32.3	42.5	44.4	61.6	63.0	70.0	73.5	76.3	70.0	60.6	54.6	44.3	57.8
1938	44.0	46.4	49.3	54.4	60.2	69.3*	70.7	70.3*	70.0*	61.1	45.4	46.2	57.3
1939	40.0	37.1	50.3	57.4	62.8	72.4	74.4	76.1	66.9	55.8	49.0	48.2	57.5
1940	43.0	44.9	50.0	55.4	63.8	70.5	72.6	72.5	68.4	60.0	46.5	47.4	57.9
1941	42.0	46.8	49.3	48.5	60.6	67.1	71.8	70.4	67.4	56.1	45.3	44.8	55.8
1942	42.9	41.7	46.4	54.8	61.5	69.8	76.3	71.4	69.4	58.4	52.8*	45.7*	57.6
1943	45.5	48.2	53.4	60.3	66.5*	73.8	75.4	70.6*	68.5	57.6	50.7*	43.4	59.5
1944	40.0	41.6	47.3	51.7*	59.8	67.8	73.2	72.3	68.3	62.9	47.3	41.3	56.1
1945	41.3*	44.6	46.2	52.4	60.9*	66.2	74.9	72.0	67.7	61.4*	50.8	42.9*	56.7
1946	38.4	43.4	49.6	60.2*	60.8	73.4	73.3	73.2*	71.4*	57.4	45.6	44.1	57.6
1947	37.2	45.5	47.2	53.0	63.2	69.1	73.7	70.7*	69.5*	59.2	44.1	37.4	55.8
1948	41.8	40.9	44.5	56.1	62.2	69.7	73.5	69.6*	66.6*	57.0*	42.2	42.6	55.6
1949	33.4	41.8	49.1	56.1	61.8	70.9	72.6	70.6	69.7	53.6	52.6	40.2	56.0
1950	42.9	47.1	50.9*	57.1*	60.1*	70.8	71.1	70.4*	63.7	62.8	49.8*	44.0	57.5
1951	38.2	42.8	46.3	52.8*	60.1*	66.1	75.1*	70.4	67.9	59.9	47.8*	40.9*	55.7
1952	42.0*	39.2*	38.6*	50.6*	62.0	71.1	73.6	71.6	67.9	63.0	46.6*	40.3*	55.5
1953	43.4*	41.4*	48.8	53.8	55.9*	71.6*	72.5*	74.3*	70.0*	59.8	50.1	37.7	56.6
1954	43.7	48.5	48.1	59.7	63.4	70.4	74.2	69.8*	70.4*	61.4	50.0	41.7	58.4
1955	36.0	38.6	48.4	52.5	58.8	69.0	69.3	68.1*	64.3	58.8	47.3	44.9	54.7
1956	47.0*	39.6*	47.9	50.2*	62.0	71.6*	69.9	66.4	67.3	56.7	42.7	39.0	55.0
1957	41.7	48.6*	47.5*	53.1*	59.0	74.2	75.9	72.3	68.4	57.8	44.6	45.7	57.4
1958	40.6	45.9	44.4	54.3	66.9	73.8	73.8	71.8	67.4	58.2	48.4	46.0	57.6
1959	45.2	43.2	48.6	58.3	62.0	74.4	75.3	70.7	68.1*	59.1	48.0	42.6	58.0
1960	37.9	39.9	52.5	55.4	61.5*	73.6	75.1	73.0	69.5	57.5	50.7	40.9	57.3
1961	42.9	44.4	49.2	56.8*	63.8*	73.8	74.9	71.8*	67.1	58.2	47.2	42.6*	57.7
1962	41.2	46.8	43.7	58.3	61.3	69.5	73.8*	75.6*	69.8	60.3	52.8	44.6*	58.1
1963	41.2	47.6	48.8	54.9	65.3*	69.7	76.1	70.8	69.6	61.9	49.3	42.6	58.1
1964	37.9	38.3	45.0*	52.2	61.9	70.4	74.5	70.8*	65.7	60.2	46.1	44.3	55.6*
1965	44.8	42.0	45.9	54.4*	59.5	66.9	74.1	72.6	66.0*	60.1	52.8	43.3	65.9*
1966	38.6	39.0	50.3	56.1	64.8	71.6	75.4	72.1	66.9*	57.7	51.9	42.7	57.3*
1967	42.9	45.6	52.3*	54.1	61.1	69.7	73.4*	71.6	67.9	60.3	52.3	40.0	57.6*

*Missing or incomplete data that was pro-rated from surroundinging stations.

Table 3. Monthly Precipitation for Patagonia Station--Elevation 4044 ft.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1935	1.29	1.65	1.10	0.00	0.51	0.00	2.56	8.57	1.86	0.00	2.77	1.58	21.89
1936	0.96	1.21	0.27	0.00	T	T	5.52	4.75	2.21	0.12	1.17	1.08	17.29
1937	2.60	0.08	0.75	0.00	0.14	0.46	3.06	3.94	1.89	1.15	0.00	1.51	15.58
1938	0.78	1.26	1.11	0.13	0.12	1.21	2.22	4.91	0.86	0.00	0.00	1.32	13.92
1939	1.04	1.98	0.18	0.13	0.00	0.25	2.96	4.55	1.64	1.11	0.59	0.76	15.19
1940	0.61	3.05	0.26	0.20	0.33	2.33	3.49	3.50	2.48	0.10	1.16	3.77	21.28
1941	1.52	1.77	0.71	1.56	0.39	0.35	2.82	2.59	3.47	0.76	0.22	2.39	18.55
1942	0.78	1.23	0.26	2.07	0.00	0.00	2.01	1.49	1.15	0.91	0.00	0.14	10.04
1943	1.47	T	0.34	0.00	0.00	1.10	2.42	5.86	1.88	0.51	0.00	0.86	14.44
1944	0.68	2.06	1.90	0.46	T	0.26	1.46	3.85	1.63	0.58	1.92	2.11	16.91
1945	0.94	0.18	1.48	0.10	0.00	0.00	3.65	5.26	0.88	2.26	0.00	0.17	14.92
1946	2.13	T	0.57	0.32	0.00	0.00	4.69	2.91	6.74	0.90	0.73	0.07	19.06
1947	0.41	0.35	0.32	0.10	0.53	0.00	2.43	3.38	1.25	0.40	1.05	0.65	10.87
1948	0.00	2.05	0.41	0.00	0.00	0.08	5.58	4.48	2.00	0.44	0.01	1.63	16.68
1949	3.03	0.92	0.46	0.14	0.00	0.49	6.07	2.25	3.19	0.72	0.28	2.18	19.73
1950	0.81	0.95	0.11	0.00	0.04	0.44	9.60	1.48	1.35	T	0.00	T	14.78
1951	1.93	0.21	0.36	1.49	0.04	0.00	3.31	5.75	1.67	2.54	1.56	1.96	20.82
1952	1.06	0.22	3.14	1.82	0.64	0.87	3.48	6.87	1.15	0.00	1.82	1.15	22.22
1953	0.19	1.40	0.91	0.06	0.17	0.23	6.84	2.19	0.00	0.28	0.13	0.12	12.52
1954	1.36	0.11	2.75	0.00	1.20	1.06	9.26	5.28	0.66	0.37	0.00	0.03	22.08
1955	3.10	0.35	0.12	0.00	0.00	0.00	6.87	7.16	0.18	0.31	0.09	0.31	18.49
1956	0.89	0.49	0.00	0.21	0.05	0.13	5.70	1.48	0.01	0.27	0.09	0.25	9.57
1957	3.06	0.29	1.39	0.42	0.42	0.11	3.27	4.17	0.13	1.97	0.18	0.70	16.11
1958	0.02	1.68	3.84	0.38	T	1.12	5.42	3.08	2.22	1.10	1.28	0.00	20.14
1959	0.00	1.13	T	0.23	0.00	0.53	6.11	3.07	0.56	1.88	2.24	1.84	17.59
1960	3.28	0.44	0.63	0.00	0.00	0.03	3.15	6.47	1.56	2.68	0.15	0.73	19.12
1961	1.18	0.11	0.25	0.00	0.00	1.10	3.30	6.12	2.43	3.37	0.23	3.02	21.11
1962	2.14	0.51	1.14	0.09	0.00	0.12	2.84	0.99	1.76	0.43	0.48	1.71	12.21
1963	0.97	1.18	0.27	0.47	T	0.00*	4.94	5.89	2.53	0.69	2.20	0.53	19.67
1964	0.44	0.08	0.71	0.42	0.00	0.43	4.84	4.74	8.13	1.43	1.27	0.52	23.01
1965	0.20	0.66	0.41	0.50	T	0.09	4.30	2.30	3.18	0.19	0.70	8.62	21.15
1966	2.02	2.26	0.07	0.02	0.07	0.08	5.79	5.82	3.97	0.55	0.95	0.82	22.42
1967	0.02	0.35	0.23	0.35	0.65	0.87	4.33	3.93	1.80	0.55	0.67	6.80	20.55

*Missing or incomplete data that was pro-rated from surrounding stations.

Table 4. Monthly Precipitation for Canelo Station--Elevation 4985 ft.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept..	Oct.	Nov.	Dec.	Annual
1935	1.39	3.63	0.90	0.15	0.13	0.06	3.24	6.36	2.77	0.00	2.12	1.35	22.10
1936	1.04	1.01	0.20	0.00	0.10	0.62	4.16	5.29	2.27	0.16*	2.02	1.54	18.41*
1937	1.92	0.25	1.40	0.10	0.01	1.50	2.26	4.08	2.00	1.11	T	2.18	16.81
1938	0.80	0.92	1.26	0.15	0.22	1.51	2.88	4.08	2.15	T	T	1.93	15.90
1939	0.77	1.24	0.59	0.11	0.00	0.40	2.55	4.52	2.80	1.10	0.55	0.67	15.30
1940	0.65	3.51	0.20	0.30	0.09	3.40	2.25	4.17	1.27	0.60	0.99	3.05	20.48
1941	2.03	1.59	0.78	1.28	0.32	0.41	1.17	3.41	2.14	0.31	0.48	2.69	16.61
1942	0.87	1.43	0.21	2.06	0.00	0.06	2.81	2.70	0.85	0.83	0.00	0.87	12.69
1943	0.88	0.17	0.49	0.00	T	1.74	2.71	6.17	0.97	0.64	T	1.33	15.10
1944	1.05	1.32	1.38	0.52	0.00	0.19	3.99	3.66	2.47	0.87	1.76	1.55	18.76
1945	1.10	0.32	1.32	0.28	0.00	0.00	3.54	5.97	1.02	2.30	0.00	0.15	16.00
1946	2.30	0.10	0.50	0.07	0.00	0.15	6.44	6.13	2.57	1.16	0.65	0.61	20.68
1947	0.46	0.47	0.12	0.16	0.42	0.04	2.00	6.66	0.75	0.68	0.82	0.72	13.30
1948	T	1.90	0.88	0.00	0.00	0.42	3.96	5.47	2.20	0.55	T	1.86	17.24
1949	3.01	0.80	0.35	0.11	0.00	1.11	4.10	3.72	3.03	1.62	0.10	2.01	19.96
1950	0.74	0.92	0.29	0.00	T	1.25	10.02	1.13	T	0.04	0.00	0.00	14.39
1951	1.56	0.37	0.32	2.50	0.00	0.00	5.30	5.99	0.67	1.58	1.24*	2.18	21.71*
1952	1.24	0.42	2.72*	1.82	0.58	1.16	3.51	3.68	0.49	0.00	1.90	1.83*	19.35
1953	T	1.50	1.00	0.08	0.00	T	3.34*	1.08	0.00	0.10	0.02	0.15	7.27
1954	1.18	0.17	2.29	0.00	0.53	0.84	2.44	7.66*	3.18*	0.70	0.00	0.02	19.01
1955	1.93	0.47	0.31	0.00	0.04	0.00	6.47	8.85	0.06	1.25	0.22	0.26	19.86
1956	0.91	0.36	0.00	0.20	0.00	0.52	7.45	3.26	0.00	0.30	0.08	0.33	13.41
1957	2.69	.18*	1.16*	0.10*	0.28	0.81	3.39	4.92	0.07	1.73	0.37	0.52	16.22
1958	0.08	1.62	3.27	0.44	0.00	4.89	6.75	4.52	2.53	0.92	0.87	0.00	25.89
1959	0.00	1.52	0.00	0.12	0.00	0.69	6.70	5.51	0.24	2.12	1.33	1.72	19.95
1960	2.58	0.52	0.16	0.00	0.00	0.17	2.71	4.53	1.51	1.57	T	0.72	14.47
1961	1.00	0.30	0.10	0.00	0.00	2.24	3.15	4.50	2.07	2.89	0.51	2.55	19.31
1962	2.08	0.26	1.28	0.05	0.00	0.10	3.06	0.34	2.36	0.70	0.32	1.65	12.20
1963	0.80	1.00	0.26	0.39	0.00	0.00	6.21	4.91	1.70	0.65	2.21	0.61	18.74
1964	0.32	0.02	0.74	0.26	0.00	0.20	7.65	4.46	4.87	1.26	0.83	0.35	20.96
1965	0.44	0.68	0.49	0.19	0.14	3.46	4.03	0.69	T	0.35	8.21	6.98	19.17
1966	1.61	1.74	0.09	0.12	0.18	0.17	4.35	5.31	3.48	0.08	0.65	0.48	18.26
1967	0.04	0.52	0.19	0.32	0.31	1.46	4.97	3.22	3.03	2.03	0.53	5.19	21.81

*Missing or incomplete data that was pro-rated from surrounding stations.

Table 5. Total Wind Movement (Miles) at Nogales 2 N, Arizona

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1953			1859	1963	2193	1972	1147	809	844	1566	1382	1652	
1954	1716	1568	2270	1507	1652	1299	761	292	596	232	353	973	13219
1955	1640	1742	2162	2064	2072	1854	643	316	708	658	697	1142	15698
1956	1247	2211	2103	2136	1889	1951	1505	682	1094	1735	1449	1672	19674
1957	1979	1558	2136	1727	2340	2154	1603	668	1228	1983	1367	896	19639
1958	1420	1267	1705	1324	1229	1338	935	416	539	835	927	1223	13158
1959	1779	1958	1968	1794	2091	1625	1063	-	658	1335	1112	1573	
1960	1728	1763	1609	1834	1830	1276	1440	836	494	914	862	1268	15854
1961	1170	1508	2445	2146	2071	1878	1502	770	719	979	776	903	16867
1962	1512	1500	1951	1838	1763	1358	1004	898	756	1212	911	1029	15732
1963	1242	1334	2102	1654	1373	305	1188	417	477	520	635	-	
1964	1602	1748	2163	1953	1595	1700	1212	499	326	964	1211	-	
1965	1214	1505	1076	1847	1612	1804	857	650	1339	1524	1398	1793	
1966	1588	1591	1785	1536	1701	1539	1249	704	649	1083	1357	1302	16084
1967	1433	1537	2138	2187	1736	1798	861	616	672	733	852	1497	16060
1968													

Table 6. Evaporation (Inches) at Nogales 2 N, Arizona

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1952										8.40	4.28	2.80	
1953	4.26	4.62	6.98	9.28	11.90	15.11	9.74	9.77	10.45	8.77	5.34	3.88	100.10
1954	4.35	6.07	7.64	10.22	11.83	13.32	6.55		7.11	5.09	5.20	4.16	
1955		4.27	7.67	12.01	15.29	16.30	9.97	5.08	8.32	7.98	5.58	3.74	
1956	4.17	4.93	9.83	11.27	14.87	14.73	10.36	7.54	9.34	8.29	4.36	3.58	103.27
1957	2.90	4.08	6.36	9.66	12.91	16.07	12.34	7.51	9.65	6.22	3.86	3.00	94.56
1958	3.60	3.97		8.45	12.53	13.05	11.16		5.85	5.64	3.87	3.83	
1959	4.15	4.14	8.26	9.65	13.20	12.16	9.33	5.52	6.98	6.85	3.60	3.40	87.24
1960		4.43	7.10	9.75	12.62	12.65	11.13	8.02	7.48	5.85	4.37		
1961	2.80	5.02	7.36	9.93	13.00	13.65	9.96	6.90	6.11	6.38		2.27	
1962	2.99	4.55	5.79	9.51	11.88	12.13	9.14	9.56	6.51	6.89	4.61	2.50	86.06
1963	3.02	4.93	7.97	9.29	11.70	14.32	10.22	5.68	7.35	6.23	3.92		
1964	3.77	4.84	6.97	10.06	12.58	13.80	9.03	6.75	5.61	6.05	3.70	-	-
1965	3.74	4.59	-	9.35	12.93	14.46	9.96	8.61	9.55	9.09	4.33	-	-
1966	4.05	4.59	7.84	11.01	15.22	16.01	11.33	8.19	6.97	8.41	5.14	3.85	102.61
1967	4.44	6.95	10.66	12.62	11.87	13.96	9.11	7.99	6.66	6.25	4.59	3.02	98.12
1968													

Table 7. Total Wind Movement (Miles) at Tucson

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1935	919	1566	837	1172	1360	1030	1169	765	646	709	556	759	11483
1936	387	713	858	933	820	805	1064	899	849	800	1000	603	9731
1937	620	671	639	473	415	842	1060	1025	709	716	545	939	-
1938	721	769	1112	1130	1363	1105	891	772	664	823	898	585	10833
1939	822	774	736	875	605	805	938	794	889	953	870	381	9442
1940	533	544	919	989	880	711	825	650	434	697	792	648	8622
1941	648	670	825	813	816	795	631	314	262	344	308	281	6707
1942	534	569	864	896	1064	1035	807	616	444	703	557	882	8971
1943	882	811	881	848	942	1024	660	481	662	735	581	542	9049
1944	584	609	1051	967	675	805	434	257	538	712	579	441	7652
1945	444	557	845	970	990	718	814	550	522	466	285	447	7608
1946	935	445	753	701	622	493	514	154	278	406	371	348	6020
1947	1188	353	632	978	912	952	769	673	556	540	574	655	8782
1948	480	722	957	742	713	892	780	692	791	741	519	392	8421
1949	582	318	411	441	496	615	437	556	550	663	503	502	6074
1950	497	389	742	642	642	527	405	214	435	553	782	681	-
1951	807	1007	1133	1155	1040	794	1096	1086	922	953	911	899	11866
1952	818	1036	1088	1046	1011	927	975	823	838	522	767	811	10662
1953	636	1016	809	998	1041	662	720	561	659	1263	947	1120	10432
1954	660	999	766	663	849	791	960	792	754	621	686	766	9307
1955	909	954	1206	1131	1206	1186	1140	965	1002	808	885	881	12273
1956	977	905	814	1042	899	908	945	693	472	494	707	768	-
1957	807	474	1027	1175	1225	1005	826	784	718	949	717	686	10393
1958	878	707	984	1123	1036	959	946	779	831	999	641	514	10397
1959	739	830	1010	1111	1368	1081	1222	816	905	893	720	885	11580
1960	795	880	802	972	891	606	985	677	614	467	287	614	8590
1961	788	706	1084	992	1264	1684	1652	1418	1379	1574	1398	869	-
1962	1639	1021	1232	1001	1356	1014	1036	824	-	541	462	471	-
1963	453	524	1003	874	510	703	1382	269	860	499	737		
1964	767	593	1072	951	571	811	420	345	434	525	268	343	6961
1965	255	363	462	569	585	758	667	504	549	576	333	380	6001
1966	321	576	298	457	734	583	414	422	544	323	305	404	5381
1967	442	407	475	515	538	516	379	443	610	289	-	-	-
1968													

Appendix VI

Geology

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APPENDIX VI

GEOLOGY

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NO. 1

SUMMARY AND CONCLUSIONS

The Redrock Canyon Watershed is a contributor to the Sonoita Creek Groundwater Basin; both being contained within the Basin and Range geomorphic province. Dominant rock units within the watershed are alluvium and flows of andesite and rhyolite. The dominant structural trend is northwest-southeast; secondary structural trends are east-west and northeast-southwest. Surface flow occurs in both the watershed and Sonoita Creek when the near surface presence of igneous rock of relatively low permeability forces the water table to intersect the ground surface. Within the watershed surface flow ceases when the volume of high permeability alluvium exceeds the volume of the surface flow thereby allowing the water table to sink below the ground surface. Indications are that the groundwater of Redrock Canyon Watershed is all going to the Sonoita Creek ground water basin. However, extensive fracturing of the igneous rocks allows the near surface flow to deviate considerably from the stream channel flow.

NO. 2

GEOMORPHOLOGY

Redrock Canyon is a tributary of Sonoita Creek and is a part of the Sonoita Creek Basin. The Sonoita Creek Basin is situated in the Mexican Highland section of the Basin and Range Geomorphic province of Fenneman (1946).

Sonoita Creek is an ephemeral and intermittent stream from its headwaters near the town of Sonoita to a point approximately 200 feet south of the town of Patagonia. South of this point, Sonoita Creek is a perennial stream. North of Patagonia, Sonoita Creek is in a narrow intermountain alluvial valley bordered by terraces of outwash gravel. South of Patagonia, Sonoita Creek enters a rock-walled canyon which continues for several miles.

The Redrock Canyon Watershed is an ovoid shaped watershed trending northwest-southeast. It is seven miles long and five miles wide at its widest point. The highland areas that form the drainage divides of the watershed are Kunde Mountain and Mount Hughes on the northwest; the Canelo Hills on the northeast; the Meadow Valley Flat divide on the southeast; and Saddle, Indian Head, North Saddle, and Kunde Mountains on the southwest. Topographic elevations range from a minimum of 4,300 feet at Dam Site "A" to

a maximum of 5953 feet southeast of Mount Hughes. However, the majority of the watershed lies below 5200 feet. Stream gradients within the watershed range from a low of 70 feet per mile to a maximum of 380 feet per mile. The overall stream gradient east of Dam Site "A" is 127 feet per mile. That portion of the watercourse between Dam Site "A" and its confluence with Sonoita Creek has a stream gradient of 59 feet per mile.

Topographic expression within the Redrock Canyon Watershed is characterized by rugged mountains; gentle, rolling detrital slopes; and wide, aggrading alluvium filled valleys.

NO. 3

GENERAL GEOLOGY

A. Stratigraphic Units

Rock types encountered in the area include alluvium of Quaternary and Tertiary Age, limestones of Permian Age, and a varied sequence of volcanics of Tertiary, Triassic and Jurassic Age. The generalized geologic map presented was compiled from maps by Wilson (1960), Feth (1948), and Schrader (1915).

1. Sedimentary Rocks

Nassereddin (P. 7, 1967) has divided the alluvium in the Upper Sonoita Creek Basin into five units "according to their stratigraphic and topographic positions, lithology, and relative degrees of permeability". The following is quoted from Nassereddin, (1967, p. 7-8):

"Alluvial Unit No. 5 was deposited on the basement rocks of the Sonoita Creek Basin. The unit is composed of erosion products of volcanic rocks from high hills. Following partial erosion of Unit No. 5, alluvial unit No. 4 was deposited. Alluvial unit No. 4 crops out over most of the basin. Partial erosion of alluvial unit No. 4 and tilting to the northwest of Units No. 5 and 4 preceded the deposition of unit No. 3. Unit No. 3 was stripped in much of the area during periods of erosion that proceeded in steps. Several terrace levels resulted and unit No. 2 is the deposit covering the terrace levels. The youngest and lowest deposit was laid down in relative deep deep channels under the present stream flood plain and forms alluvial unit No. 1".

Alluvial unit No. 1 is of Quaternary Age; units No. 2 through No. 5 are of Tertiary Age. Within the upper Sonoita Creek Basin groundwater is produced from alluvial units No. 1 and No. 4 with unit No. 4 being the greater producer.

Alluvial unit No. 1 and an older sequence, which probably corresponds to Nassereddin's unit No. 2 are the only alluvial units occurring within the Redrock Canyon Watershed. The older alluvial unit, or unit No. 2, forms terrace deposits on either side of Redrock Canyon and its tributaries. The unit consists of clay, silt, sand, gravel, and boulder deposits. The constituent particles of the terrace deposits are poorly sorted, weakly cemented, and appear to be locally derived. Due to the presence of fine particles it is felt that this unit, in general, would have low permeability and be a poor aquifer. Locally where sands and gravels predominate over the fines, permeability would improve. However, gullying of this unit to the local stream level makes it unlikely that any appreciable amount of water remains long in the terrace deposits above the local stream level.

The average exposed thickness of older alluvium is five feet. However, seismic data indicates thicknesses of up to 27 feet.

Nassereddin (1967, p. 16) states: "The designation alluvial unit No. 1

is used for the unconsolidated sand, silt, clay and gravel stream deposits that directly underlies the flood plains of Sonoita Creek and its tributaries". He further states on page 18: "Alluvial unit No. 1 is unconsolidated poorly sorted, fine to coarse grained, and weakly cemented". Within the confines of the Redrock Canyon Watershed alluvial unit No. 1 consists predominantly of coarse sands to gravel.

Seismic data indicates an average maximum thickness of 20 feet for the recent alluvium (alluvial unit No. 1).

Sedimentary rocks of Permian age are represented in the area by the Concha limestone, the Scherrer Formation consisting of a quartzose sandstone and a dolomite, and the Epitaph Dolomite. These sedimentary rocks occur on the Canelo Hills northeast of Lampshire Canyon and therefore cover only a small portion of the Redrock Canyon Watershed. Feth (1948, p. 86) measured 2223 feet of Permian sediments in the northern Canelo Hills. Due to their limited occurrence within the Redrock Canyon Watershed, they are not considered to be important hydrologically.

2. Igneous Rocks

Extrusive igneous rocks are the dominant rock type found in the Redrock Canyon Watershed. The rocks consist of andesite lava flows of Tertiary Age (Schrader, 1915, p. 75) and a complex set of silicic volcanics of Jurassic-Triassic Age called the Canelo

Hills Volcanics (Hayes, et.al. 1965). Schrader (1915, p. 75) described the andesite as follows: "The andesite...is a dark-gray to reddish-brown rock with a brownish felsitic to glassy ground mass and is usually porphyritic, with medium-sized phenocrysts of oligoclase-andesine-labradorite and smaller forms of hornblende, biotite, augite and hypersthene..."

The average exposed thickness of the andesite is 500 feet (Nassereddin, 1967, p. 8). In the Redrock Canyon Watershed the andesite is highly fractured and in many places deeply weathered.

Core drilling at Dam Site "A" by the Arizona Fish and Game Department indicates that the zone of weathering and extreme fracturing extends to a depth of up to 29 feet. However, the average depth of weathering and extreme fracturing is approximately 13 feet.

(Hayes et.al. 1965, p. 2) has divided the Canelo Hills Volcanics into three units: "basal interbedded volcanic and sedimentary rocks, rhyolitic lavas, and an upper welded tuff." In the Redrock Canyon Watershed the Canelo Hills Volcanics are represented by extensive rhyolitic lava flows. The rhyolite is a coarsely porphyritic, light-gray, massive, siliceous rock. Schrader (1915, p. 71) states: "It is composed principally of a dense glassy pale-brownish ground mass in which are embedded numerous phenocrysts of orthoclase,

quartz, a little sodic plagioclase and small amounts of biolite, augite and hornblende."

The weathered rhyolite flows are stained reddish brown by iron oxide. The approximate exposed thickness of the rhyolitic flows is 2,000 feet (Nassereddin, 1967, p. 10).

B. Structure

Sonoita Creek Basin and its tributary Redrock Canyon Watershed are within the Basin and Range geomorphic province. Therefore, they are characterized by fault-block structures which have generated a complex system of folds and fractures. The major structural trend within the area is northwest-southeast.

1. Folding

The Canelo Hills form the northeast divide of the watershed. Schrader (1915, p. 240) states: "The general structure is that of a monocline dipping to the southwest, with a fault plane somewhere along the northeastern flank of the hills. The sediments strike N35°W, and dip 15°-30° SW (Schrader, 1915, p. 240).

Monkey Canyon SW drains the northern Canelo Hills approximately a mile and a half north of Mount Hughes. An anticlinal fold axis striking N45°W follows the trend of Monkey Canyon SW (Feth, 1948, p. 106).

A northwest-southeast trending fold occurring on the west side of Sonoita Creek is mentioned by Nassereddin (1967, p. 28).

2. <u>Faulting</u>

A fault may be defined as "a fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture" (AGI, 1962, p. 176).

Topographic forms and alignments within the Basin and Range province are due, in large part, to faulting. To the north of Redrock Canyon Watershed Feth (1948, p. 105) has mapped a complex series of high-angle faults in the northern Canelo Hills. Two dominant fault trends are noted: one strikes N80°W, the other trend strikes N30°E. Hayes et.al. (1965, p. 2) has mapped a dominant fault trend striking N45°W throughout the Canelo Hills. Along the northeast flank of the northern Canelo Hills Simons et.al. (1966, p. 15) mapped faults trending generally east-west and northwest-southeast.

The northwest-southeast alignment of hills and knobs within the Redrock Canyon Watershed paralleling the alignment of the Canelo Hills is undoubtedly due to the faults striking in the same direction. The straight and narrow valley of Sonoita Creek between Patagonia and the Rail X Ranch indicates that this

portion of Sonoita Creek is controlled by a fault paralleling the valley and striking approximately N20°E.

3. Jointing

A joint may be defined as a "fracture in rock, generally more or less vertical or transverse to bedding, along which no appreciable movement has occurred" (AGI, 1962, p. 269). Faulting and jointing are intimately associated. The primary distinction between the two is that in faulting, movement is parallel to the fracture plane; in jointing any movement is perpendicular to the fracture plane.

The igneous rocks exposed in the Redrock Canyon Watershed are highly fractured. Three dominant joint sets have been observed with the following strike trends: N80°W to S70°W, N30° to 40°E, and N45°W. The observed joint strikes are in agreement with the fault strikes recorded above. In addition to this many lineaments of color tone, vegetation, drainage, and structure may be observed on the air photos. The observed lineaments further substantiate the given fracture trends.

Fractures are zones of weakness. As such erosion proceeds more rapidly along fractures than in nonfractured areas. A consequence of this is that the streams are fracture controlled; the streams follow the fracture directions. This is strongly exemplified within the Redrock Canyon Watershed.

NO. 4

HYDROGEOLOGY

A. Definitions and Principles

Subsurface water is all water which exists below the ground surface. Groundwater is that portion of the subsurface water that occurs below the zone of saturation; the water table defines its upper limit. The zone of aeration forms the interval between the ground surface and the water table. Vadose water is water within the zone of aeration; it is in transit from the surface to the zone of saturation at which point it becomes a part of the groundwater system. The source of most groundwater is precipitation in the form of both rain and snow. It enters the groundwater system by infiltration through the soil. When for any reason the water table intersects the ground surface, water leaves the groundwater system and becomes part of the surface flow.

Geologic structure and stratigraphy strongly influence both the direction and rate of flow of groundwater. In general, groundwater flow tends to follow the dip of inclined strata. The lithologic character of a stratum determines its permeability. The coefficient of permeability is a measure of a lithologic unit's ability to transmit water. Dense extrusive rocks such as andesite and rhyolite usually have low coefficients of permeability. Fracturing of the

rock greatly enhances its coefficient of permeability.

B. Redrock Canyon Watershed

The watercourses making up the Redrock Canyon Watershed are intermittent streams. Flowing water appears and disappears at many locations within the watershed area. The igneous rocks of the area cannot transmit water as rapidly as the recent alluvium as indicated by their coefficients of permeability. Therefore, when relatively unfractured igneous rocks intersect the stream bed at or close to the surface it functions as a natural dam or groundwater barrier. Groundwater accumulates upstream from the barrier until the alluvium becomes saturated and the water table intersects the ground surface. The result is surface runoff. Surface flow continues downstream from the barrier to a point where the volume of alluvium present has a capacity to transmit more water than is being supplied by the surface flow. At this point surface flow ceases and the water table again drops below the ground surface. This process is repeated many times within the Redrock Canyon Watershed.

The elevation of the water table was determined at random points by measuring the static water level in wells, by seismic measurements, and by observation of the intersection of the water table with the ground surface. The data provides a means of determining the configuration of the water table which in turn indicates the direction of groundwater flow. The number of measurements obtained were too meager

to construct an accurate picture. However, the data indicates that the groundwater flow generally conforms to the topography of the watershed.

The southwesterly dipping Canelo Hills strata act as a groundwater barrier preventing the loss of groundwater to the northeast. Seismic and drilling data indicate that fracturing of the rock (joints) do not extend to sufficient depths to allow an appreciable loss of groundwater from the area. However, it should be noted that the near surface fracturing is of sufficient density to allow the flow direction of shallow groundwater to deviate considerably from the flow direction of the surface stream channels.

C. Sonoita Creek

The transition of Sonoita Creek from an ephemeral and intermittent stream to a perennial stream approximately 200 feet south of Patagonia is a result of the water table intersecting the ground surface. As in Redrock Canyon, andesite intersecting the stream channel has formed a groundwater barrier forcing the water table to the ground surface. The andesite outcrops in the stream channel approximately one half mile south of Patagonia. The water issuing forth as perennial stream flow is derived from the entire Sonoita Creek groundwater basin. The Redrock Canyon groundwater is only one of many contributors to the Sonoita Creek groundwater basin.

NO. 6

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Table 1. Geophysical Investigation - Seismic Refraction Data

Seismic refraction techniques were used to determine depths to bedrock. The equipment utilized was a GT-2B Portable Refraction System complete with photographic recorder, motor driven optics, one timing trace, and twelve time break traces. Geophone cable spreads of 10 and 20 foot spacing between geophones were used. The seismic shock source was generated by a No. 4 electric blasting cap and 0.4 meters of 50 grain primacord buried 45 centimeters in the ground. The results of the refraction seismic survey are tabulated below:

Table 1. Tabulation of Refraction Seismic Data

Location	V_1	V_2	V_3	d_1	d_2	Remarks
Dam Site "A"	11000					Control shot on andesite outcrop
Dam Site "A" - middle of wash Cable spread: N85E	5625	12000		15		Magnitude of V_1 indicates that major portion of alluvium is saturated
Confluence of Lampshire and Red Rock Canyons - middle of wash Cable spread: N42E	1429	5714	10000	8	23	V_1 indicates unsaturated alluvium, V_2 indicates saturated alluvium, V_3 includes andesite. Therefore d_1 represents depth to water table and d_2 represents depth to bedrock
Red Bank Well - Terrace on north bank Cable spread: N50W	5294	15000		27		V_1 represents both unsaturated and saturated terrace materials. Water level in well within 20 ft. of shot point stands at 16 ft. below the surface. Large boulders of high velocity rhyolite within the terrace materials increases its overall velocity so that it is not possible to define the water table. V_3 indicates rhyolite bedrock.
Red Bank Well - Terrace on south bank approx. 276' S28W from north bank shot point Cable spread: N50W	5833	12500		22		See remarks for north bank shot point

Table 1. - Continued

Location	V_1	V_2	V_3	d_1	d_2	Remarks
Red Bank Well - middle of wash in recent alluvium between north and south bank shot points Cable spread: N50W	5455	1000		19		See remarks for north bank shot point
USGS Gaging Station - On Sonoita Creek - Northwest side of stream in recent alluvium Cable spread: N40E	6057	1000		36		V_1 indicates saturated alluvium - exposed alluvium has high coarse gravel content. V_2 indicates andesite bedrock.
Kunde Ranch Spur Road - T22S, R16E, S2 NW/4 of SW/4 of NE/4 Cable spread: N40E	2000	4781		6		V_1 indicates overburden (clay loam) V_2 indicates weathered andesite
Candelario Peak Road - T22S, R16E, S2 NE/4 of NE/4 of NE/4 Cable spread: N48W	1923	3333		13		V_1 indicates overburden (clay loam) V_2 indicates highly weathered andesite

Note: V_1 = Average seismic velocity in pt./sec of first layer
V_2 = " " " " " " second layer
V_3 = " " " " " " third layer
d_1 = Depth in ft. to interface between first and second layer
d_2 = " " " " " " second and third layer

Table 2. Estimated Hydrologic Properties of Stratigraphic Units

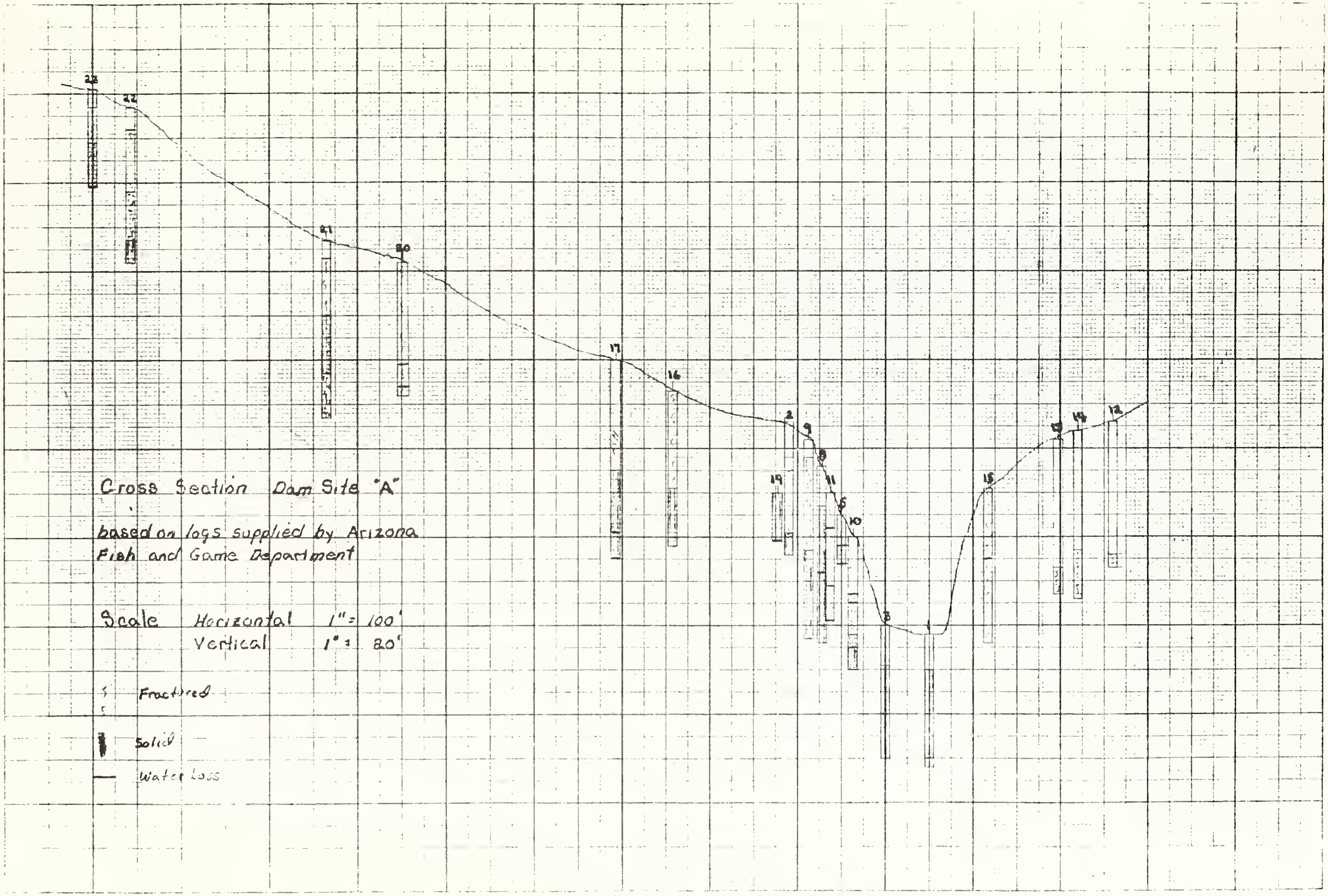
	Coefficient of Permeability	Specific Yield	Specific Retention
Recent alluvium	5000 gal/day/ft^2	5%	25%
Older alluvium	1-300 " " "	4-30%	6-30%
Andesite and rhyolite			
Weathered	4 " " "		
Fractured	20 " " "		
Solid	0.2 " " "		

Table 3 - Water Table Elevations

Location	Well Elevation (ft)	Depth of Static Water Level (ft)	Elevation of Water Level (ft)
Seibold Well) 22-16-2aabb)	4380	20	4360
Seibold Well) 22-16-4adca)	4190	40	4150
Well) 22-17-16-dbac)	4730	8	4722
Red Bank Well) 22-17-17bbdd)	4650	18	4642
Shaft) 22-17-16dbac)	4850	20	4830
Spring) 22-16-2bbcc)			4300
Gates Spring) 22-17-7dcaa)			4590
Seibold Corral) 22-16-2aabb)	4380	20	4360
Well) 22-17-16bbca)	4730	8	4722
Shaft) 22-17-16dbac)	4850	20	4830
Red Bank Well) 22-17-17bbdd)	4650	18	4642
Spring) 22-16-2bbcc)	4300		4300
Gates Spring) 22-17-7dcaa)	4590		4590
Seibold Ranch	4190	40	4150

Table 4. Stream Gradients

	Distance Miles	Elevation From	Elevation To	Elevation Difference	Gradient ft/mi
Sonoita Creek					
Redrock to Rail X	6.21	4080	4400	320	41.53
Rail X to RR crossing	2.56	4400	4625	225	87.89
RR cross. to head	3.06	4625	4850	225	73.53
Redrock to gage	3.52	4080	3890	190	34.42
Gage to head	17.35	3890	4850	960	55.33
Redrock Creek					
Sonoita to Dam A	3.75	4080	4300	220	58.67
"A" to N fork 1 (S-26)	3.06	4300	5250	950	310.46
"A" to N fork 2 (S-24)	3.85	4300	5500	1200	311.69
"A" to N fork 3 (S-29)	3.45	4300	5150	850	246.38
"A" to Oak Grove Spr.	2.17	4300	4570	270	124.42
"A" to Lampshire	2.76	4300	4530	230	83.33
Lampshire to Red Bank Well	1.58	4530	4640	110	69.62
Red Bank to head West Fork	2.56	4640	5050	410	160.16
Red Bank to head in S-22	3.25	4640	5100	460	141.54
Red Bank to Down Under tank	2.17	4640	4890	250	115.21
Down Under to head in S-11	1.08	4890	5300	410	379.64
Down Under to head in S-14	1.77	4890	5350	460	259.89
Lampshire Canyon					
Mouth to Fk in S-6	1.08	4530	4650	120	111.11
S-6 Fk to Box Canyon (4)	1.28	4650	4850	200	156.25
Box Canyon to White Tank	2.17	4850	5320	470	216.59
Box Canyon to head in S-10	1.68	4850	5400	550	327.38
Dam Site A to head in S-14	8.28			1050	126.81


Cross Section Dam Site "A"
based on logs supplied by Arizona
Fish and Game Department
Scale Horizontal 1" = 100'
Vertical 1" = 20'
Fractured
Solid
Water Loss

Appendix VII

Soils

I. Table of Contents

Appendix VII

1. Summary and Conclusions

Soils of the Red Rock Watershed are generally shallow and stony on steep slopes of the outer perimeter area and rolling to steep surfaces of the interior basin. Heavy textured soils of variable depth occupy approximately 18 percent of the lower slopes and a section of the upper reaches of Red Rock Creek.

Revegetation within this watershed would be ineffective for increasing water yields of the soil for the following reasons:

1) Stand densities of deep-rooted trees and shrubs are too low for effective water depletion of the subsoil below depletion levels of grassland.

2) Levels of available water within the shallow profiles over 80 percent of the area are generally low. This moisture would be used primarily for evapotranspiration during dry periods.

3) Heavy textured soils within the remainder of the watershed are low in water yield and permeability, and support thin stands at deep-rooted vegetation with grass.

Revegetation within treatable areas on the Santa Rita and Patagonia Watersheds which contain dense stands of deep-rooted vegetation will effectively increase water yields to Sonoita Creek. Under the conditions of high erosion potential on each unit, this treatment practice will require careful management.

2. Soils of the Watershed and Adjacent Treatable Areas

Soils of the Red Rock Watershed vary widely in depth, texture and lateral extent according to surface physiography and the nature of parent geologic materials.

Shallow gravelly soils and rockland occupy steep slopes on igneous and sedimentary rock of the Canelo hills in the northeastern part of the watershed, and slopes of peaks and ridges along the western edge of the watershed. Minor areas of a moderately deep clay soil occupy lower benches along the base of the Canelo hills.

Moderately deep soils of medium texture occupy high meadowlands along the southeastern end of the area and extend down the slopes, forming the headwater area of Red Rock Creek. These support natural grasslands on high, exposed sites and grass-oak-chaparral plant associations on lower slopes. Moderately sloping low hills within the central portion of the watershed are occupied by shallow stony soils. There is a small area of moderately deep clay soils along the lower section of Red Rock Creek. These soils support oak woodland, chaparral and grass-woodland associations.

Soils of the treatable areas on Patagonia mountain slopes adjacent to Red Rock Watershed are shallow and stony and support juniper and oak woodland vegetation. The treatable areas of juniper and oak on the Santa Rita watersheds above Sonoita Creek are located on shallow soils derived from rhyolite, granite and igneous volcanic materials.

Hydrologic Response Units A1 and A2

These units of the Sonoita Basin include shallow and very shallow, very rocky soils on fine grained acid igneous and sedimentary rocks. Parent rocks include rhyodacite, rhyolitic welded-tuffs, rhyolite lavas, tuff conglomerate, quartz monzonite, and feldspathic sandstones. Commonly these rocks are highly fractured. The physiography of the unit includes steeply sloping mountains and foothills having many short, steep drainages and a few long axial drainages. Slopes are dominantly 35 to 50 percent but range from 30 to 60 percent. Soils of the unit include Faraway soils, shallow to very shallow, medium textured gravelly loam soil containing more than 35 percent gravel, cobble and stones in the profile.

Faraway soils make up about 70 to 80 percent of the unit. Rock outcrop makes up to 15 to 25 percent of the unit occurring as low ledges, ridges, and pinnacles. Also included in the unit are small amounts (5 to 10 percent) of Luzena gravelly loam or clay loam, occurring on intermixed basic igneous rocks.

The predominant vegetation is oak, juniper and mesquite with grass understory. Brush species are manzanita and squawberry. Grasses are plains lovegrass, sideoats, blue, hairy, and sprucetop gramas, deer grass, three awn, and some pinyon dropseed. Agave, sotol, and other cacti are also common. Percent of good cover ranges from 90 percent under grass to 60 percent under oak and juniper.

Hydrologic Response Units A3 and A4

These two units in the Sonoita Basin drainage contain the Barkerville and Gaddes soils and intermingled rock outcrop. Slopes are dominantly 35 to 50 percent. The area has many short, steep drainages and a few long drainways. The Barkerville soils are dark colored and moderately deep over highly weathered granite bedrock on mountain slopes and make up 50 to 60 percent of the unit. Textures are gravelly sandy loams, with a stone and cobble content of 0 to 30 percent. The Gaddes soils have reddish, moderately-fine textured B horizons and are 20 to 40 inches deep over weathered granite. Surface textures include gravelly sandy loam, gravelly loam, and gravelly sandy clay loam. Gravel, cobble, and stones in the profile average less than 35 percent by volume. Gaddes soils usually are on the less sloping areas and make up 20 to 30 percent of the unit. Rock outcrop occupies occasional ridges and pinnacles on low ledges and constitutes 10 to 12 percent of the units.

The vegetation is scattered trees and grass. Trees include Emory oak, pinyon pine, and juniper at low elevations and ponderosa, Chiricahua and Limber pine at higher elevations. Brush species include manzanita, squawberry, and some cliffrose. Grass species are chiefly plains lovegrass, Texas beardgrass, tanglehead, deergrass, pinyon dropseed, gramas, and three awn. Agave, sotol, and other cacti are also present.

Hydrologic Response Units 1A1, 4A1, and 7B1

These units include the Tortugas soils on moderately-steep and steep limestone hills with 30-50 percent slopes. Small areas of rock outcrop have slopes exceeding 50 percent. These shallow, medium textured soils comprise 50 to 60 percent of the unit. Surface textures are cobbly or very cobbly loams. Coarse fragments in the profile are more than 35 percent gravel, cobble and stones. Rock outcrop in the form of low ledges, ridges and pinnacles comprise 35 to 45 percent of the unit. Bedrock is usually highly fractured. HRU 7B1 includes 35 percent of the Lampshire-Graham complex which is treated under the section for HRU 8B2.

The vegetative cover includes trees, shrubs, and grass. Trees are oak and mesquite. Shrubs include mountain mahogany, ceanothus, sumac, cliffrose, manzanita, range ratany, guajillo, ocotillo, squawberry,

and some sandpaper bush. Herbaceous species are agave and sotol. Grasses include black, blue, sideoats, and sprucetop gramas, slim tridents, little bluestem, plains lovegrass, wooly bunchgrass, cane-beardgrass, deergrass, and three awn.

Hydrologic Response Units 1A2 and 4A2

The soil of these units is a deep, heavy clay soil on benchlands of the Canelo hills. Slopes range from 8 to 15 percent. This soil has a high water retaining capacity, with low water intake and transmission rates. The surface layer is a sandy loam, with 25 percent stone cover underlain by a thin gravelly clay loam having 20 percent gravel. A heavy clay B horizon extends to andesite at three feet. Gravel content decreases with depth. The soil supports a moderately-heavy stand of grass and scattered oak.

Hydrologic Response Units 1A3, 2A2, 3A3, 4A3, 5B1, 6B1, 7B2, and 8B1

Faraway soils comprise 70-80 percent of each of these units. These are shallow and very shallow, very rocky, medium textured soils on fine grained acid igneous and sedimentary rocks. The highly fractured parent rocks include various rhyolites, tuff-conglomerates and felspathic sandstones. Physiography of the units include slopes of 5 to 10 percent over the gently sloping valley floors, 10 to 25 percent over rolling areas and low mountain slopes and up to 60 percent on the steep areas. Rock outcrop makes up 15 to 25 percent of the units and occurs as low ledges, ridges and pinnacles. Small amounts of Luzena gravelly loam, a moderately-deep clay soil comprise 5-10 percent of the units on lower slopes. HRU 7B2 includes eight percent of a deep heavy clay soil which is described under HRU's 1A2 and 4A2.

Vegetation is oak and mesquite with manzanita and grass understory. Brush species are manzanita and squawberry. Grasses are plains lovegrass, sideoats, blue, hairy, and sprucetop grass, deer grass, three awn and some pinyon dropseed. Agave, sotol, and other cacti are also common. Percent of good cover ranges from 92 percent under grass to 60 percent under oak and juniper.

Hydrologic Response Units 2A1 and 3A1

These units include both the Showlow soils and the Whitehouse-Rimrock soil complex. The physiography consists of high rolling uplands and moderate slopes in the headwaters of Red Rock Creek. Showlow is a deep, well-drained, fine-textured soil developed from diorite and quartzite in old alluvium. The profile contains 5 to 10 percent gravel and stones. This soil comprises about 65 percent of HRU 2A1 and 50 percent of HRU 3A1, and occupies high grasslands and adjacent

moderate slopes with grass and scattered woodland areas. The remainder of HRU 2A1 is occupied by Faraway soils which are described under HRU 1A3.

Whitehouse and Rimrock soils constitute 50 percent of HRU 3A1. These occur in a complex pattern on nearly level to strongly sloping and rolling valley slopes dissected by moderately deep drainageways. Slopes range from 0 to 20 percent, but are dominantly 3 to 10 percent. Whitehouse soils are deep and fine textured and make up about 65 percent of the complex. They are mainly on slopes of 0 to 10 percent. Rimrock is a heavy clay soil which cracks widely when dry, and swells when wet. This soil constitutes 25 to 30 percent of the unit and occurs in slightly concave areas where dominant slopes are 0 to 5 percent. Both soils are formed in old alluvium from mixed sources including dacite, andesite, diorite, reddish siltstone, and shales.

Vegegation on these soils is grass including curly mesquite, sideoats, blue, hairy, and sprucetop gramas, three awn, and Indian wheat.

Hydrologic Response Unit 3A2 and 7B4

Rockland and rock outcrop constitute 100 percent of each of these units. Rockland contains small scattered pockets of shallow soils, with low capacity for water retention. Rock outcrop occurs in the form of high-elevation ridges and pinnacles. Vegetation density is low.

Hydrologic Response Unit 6B2 and 8B4

These units contain a complex mixture of Grabe and Comoro soils on narrow gently sloping flood plains along Red Rock Creek. The soils have formed in recent alluvium from highly mixed igneous and sedimentary materials. Slopes are dominantly 1 to 3 percent but range from 0 to 5 percent. Both soils are deep and well drained. Grabe soils have medium textures in the 10 to 40 inch zone, whereas Comoro soils are moderately coarse textured. Surface textures include loam, gravelly loam, sandy loam, and gravelly sandy loam. Overall, the Grabe and Comoro soils occur in about equal amounts and make up approximately 80 percent of the unit. Riverwash, thin soils over very sandy and gravelly materials, gravelly alluvial land, and small amounts of Pima soils make up the remaining 20 percent. Coarse fragments on the surface range from 10 to 30 percent gravel and 0 to 5 percent cobble. Most of the unit is subject to overflow.

Vegetation is grass, brush, and trees. Grasses include blue and Rothrocks gramas, three awn, muhlys, plains lovegrass, cane beardgrass, and annuals. Brush species are mesquite, desert willow, broomweed and burrow weed. Stand densities of oak and mesquite are greater than on other units of the watershed.

Hydrologic Response Units 7B3 and 8B3

The soil of these units consists of Graham gravelly or cobbly loams and gravelly or cobbly clay loams on rolling to hilly and moderately steep, low hills and ridges of dacite, andesite, or bedded andesite-tuff breccia. This soil comprises about 75 percent of the area. Slopes are dominantly 5 to 20 percent, but up to 15 percent of the area has short, steep slopes and scarps into the many narrow dissecting drainageways where bedded tuff breccia outcrops. Graham is a shallow soil with a clayey B horizon on basic igneous rocks. Lampshire very cobbly loam, a shallow and very shallow soil is a 5 to 10 percent inclusion in the rockier portions of the unit. Low ledges of rock outcrop, together with tuff outcrop in the drainages, is a 10 percent inclusion.

Vegetation is grass and brush. Grasses include sideoats, sprucetop and hairy gramas, curly mesquite, three awn, and black grama. Brush species include calliandra, mesquite, ocotillo, catclaw, mimosa, shin dagger, and barrel cactus.

Hydrologic Response Unit 8B2

Soils of this unit are of the Lampshire-Graham complex which includes shallow, rocky soils on moderate to steep mountain slopes along the west edge of the watershed. Lampshire is a very shallow medium-textured gravelly and cobbly soil on steep slopes and low ridges and constitutes 40 percent of the area. Graham soil occupies the remainder of the unit on lower slopes and rolling valley bottoms adjacent to Red Rock Creek. This soil is a shallow gravelly clay overlying basalt bedrock. Vegetation on this unit is principally grass, with scattered stands of oak and mesquite.

3. Soil Physical Characteristics and Properties Affecting Water Yield within the Hydrologic Mapping Units.

The data of Table 1 provide numerical values expressing the magnitude of each water-related soil physical property. These are utilized within the watershed analysis for the determination of the effects of environmental parameters upon water yield of the soil. These properties are the following:

1. Plant-available water storage potential in the soil and watershed parent material.
2. Transmissibility of soil and unconsolidated layers for water movement.
3. Calculated soil moisture levels at the point of greatest depletion during the year.
4. Water depletion rate of the soil under natural environmental conditions.

Water storage and transmissibility were computed from field measurements of soil texture, structure, depth and surface condition, using established reference guides.

The Hydrologic Soil Group listed for the soils of each unit is a classification which identifies the hydrologic nature of the unit as it relates to water transmission through the profile. The following list contains the components of the H.S.G. designations.

Hydrologic SoilGroup Unit Components

Group	Intake Rate in/hour	Limitations to water movement
B	2.5 - 5.0	
C	0.8 - 2.5	Shallow profiles, medium to fine textures
D	Below 0.8	Rock cover, clay horizons, shallow profiles over bedrock

Soil Depth Classes:

1. Less than 20 inches to parent material
2. Over 20 inches to parent material
3. Rock

Table 1. Physical Properties of Soils Affecting Water-yields of the Sonoita Creek Basin

Hydrologic Unit	Depth Inches	Texture*	Plant-Available Moisture Inches	Transmissibility Inches/hr.	Soil** Moisture Level July 1 Inches	Depletion Constant	Soil Group
			Sonoita Creek Watershed				
A1, A2	0-6	l	0.48	6.00	0.05	0.55	C1
	6-17	GKsl	1.10	6.50	0.25		
	17-36	R	0.15	0.01	0.30		
A3, A4	0-8	Gl, sl	0.82	4.05	0.15	0.40	C2
	8-24	R + cl	0.49	2.10	0.20		
	24-36	R	1.50	0.01	0.25		
			Red Rock Watershed				
1A1, 4A1	0-12	Kl	0.90	4.00	0.04	0.55	D1
	12-36	R	0.60	0.01	0.20		
1A2, 4A2	0-6	Gcl	0.45	0.08	0.25	0.05	D2
	6-34	c	4.64	0.01	0.50		
1A3, 2A2, 3A3, 4A3, 5B1, 6B1, 8B1	0-6	l	0.48	6.00	0.07	0.55	C1
	6-17	GKsl	1.10	2.50	0.25		
	17-36	R	0.15	0.01	0.30		
2A1	0-6	l, cl	0.58	1.00	0.05	0.55	D2
	6-17	cl, c, sl	1.40	0.08	1.00		
	17-24	R, c	0.82	0.01	0.60		
	24-34	R, c	1.40	0.01	0.90		
	34-44	R, Gscl	0.53	0.08	0.50		
3A1	0-4	Gl	0.37	4.00	0.04	0.12	D2
	4-12	c, cl	1.22	0.08	0.40		
	12-24	c	2.01	0.01	0.80		
	24-34	Gc	1.85	0.05	0.70		
	34-44	Gcl	0.60	0.10	0.70		
3A2, 7B4	0-36	R	0.30	0.01	0.30	0.02	D3
6B2, 8B4	0-36	l, sl	4.02	1.16	0.70	0.25	B2
	36-62	l, Gsl	2.17	4.00	0.90		

Hydrologic Unit	Depth Inches	Texture*	Plant-Available Moisture Inches	Transmissibility Inches/hr.	Soil** Moisture Level July 1 Inches	Depletion Constant	Soil Group
7B1	0-6	l, cl	0.54	1.00	0.07	0.55	D1
	6-12	R, c	0.60	0.01	0.10		
	12-36	R	0.20	0.01	0.20		
7B2	0-6	l, Gcl	0.47	2.10	0.10	0.55	C1
	6-17	GKsl, c	1.65	0.01	0.10		
	17-36	R, c	0.30	0.01	0.10		
7B3, 8B3	0-6	cl	0.75	0.08	0.09	0.10	D1
	6-14	c	1.43	0.01	0.10		
	14-36	R	0.20	0.01	0.20		
8B2	0-6	l, cl	0.56	1.00	0.09	0.55	D1
	6-14	R, c	0.77	0.01	0.10		
	14-36	R	0.20	0.01	0.01		

* Textural designations:

l	loam	scl	sandy clay loam
s	sand	G	gravelly
sl	sandy loam	K	cobbly
c	clay	R	bedrock
cl	clay loam		

** Lowest seasonal level for soil moisture depletion by evapotranspiration.

Table 2. Qualitative Rating of Sonoita Watershed Soils for Vegetative Production.

Hydrologic Response Unit	Area	Percent of Total Area	Range Herbage Productivity Group	Potential For Range Revegetation
	acres	%		
1A2	95		2	high
4A2	106		2	high
8B4	82		2	high
3A1	386		2	high
Total	669	3.2		
2A1	788		3	moderate
Total	788	3.7		
7B3	574		4	low
8B3	336		4	low
3A2	164		4	low
7B4	130		4	low
1A3	1118		4	low
2A2	1837		4	low
3A3	1013		4	low
4A3	1410		4	low
5B1	618		4	low
6B1	2004		4	low
7B2	1379		4	low
8B1	893		4	low
1A1	555		4	low
4A1	2327		4	low
7B1	1341		4	low
A1	520		4	low
A2	547		4	low
A3	622		4	low
A4	1535		4	low
8B2	645		4	low
Total	19,568	93.1		

4. Estimated Productivity for Grass, Shrubs and Trees

The density of vegetative cover over the Red Rock Watershed ranges from zero cover on rock surfaces and rockland through sparce on thin rocky soils of steep slopes to dense ground cover of 95 - 99 percent on grasslands of HRU units 1 and 2. Cover density, including grass, leaves and twigs varies also from poor under grass-mesquite-oak associations to good under adjacent grassy areas within HRU's 2, 5, 7, and 8.

The productivity ratings and revegetation potentials for soils of watershed units in Table 2 are based upon data obtained from all available sources in the southwest. The levels of herbage production are influenced by slope, aspect, geological parent material, soil physical characteristics, climate, plant competition and management. Following is an array showing estimated productivity values for the range herbage production groups.

Table 3. Productivity Group Classification for Sonoita Basin Soils

Group	Management Level: Good	Management Level: Poor
	Pounds of herbage per acre	
1	1500 +	700
2	1100-1400	500-600
3	750-1000	400
4	250-700	150

The opportunity for increased herbage production in Red Rock Watershed is very limited. Shallow soils of low productivity occupy 93 percent of the Red Rock basin. Conversion of low-density oak-mesquite types to grass would not yield additional water to stream channels, due to present low density of deep roots in the soil.

Soils of the treatable areas on the Santa Rita and Patagonia Mountain watersheds are generally shallow and low in productivity. Conversion of high density oak and mesquite stands to grass would increase soil moisture release to the drainages tributary to Red Rock Creek.

The Multiple Use Plan of the Ranger District lists the following species of overstory and grass types by elevation zones:

Elevation in Feet	Vegetative Types
4,500 - 5,400	manzanita, Emory and Turbinella oak, sumac, alligator juniper, Arizona whiteoak
5,500 - 6,500	manzanita, Emory, Turbinella oak, Arizona whiteoak, sumac, skunkbrush, alligator juniper, Pinon and Chiricahua pine, ceanothus
6,600 - 9,000	Silverleaf oak, Palmer and Gambel oak, Mountain mohogany, Apache, Ponderosa pine, Douglas Fir, ceanothus, Arizona Madrone.

Density of ground cover on these areas varies from 60 - 95 percent. The treatable units vary from 5 to 200 acres in size. Stand of deep-rooted species on these are of sufficient density for a vegetative conversion to yield increased streamflow.

5. Erodibility and Erosion Potential for Watershed Soils

Erosion is an important factor in the management of a watershed. This process originates with the dislodging of soil particles at any point on the watershed and transport by water down into the drainage channels, with subsequent loosening and transportation of other particles along the course. Losses of soil by water erosion result in sedimentation of water courses, reservoirs and flood control structures. Field observations indicate that the erosion rate is relatively low on soils of the Sonoita Creek basin at the present time. Cultural improvements to be constructed during development of the Red Rock Canyon for recreation or type conversion on adjacent areas must be designed to maintain erosion at low levels.

SUMMARY OF THE PHYSICAL CHARACTERISTICS AFFECTING HYDROLOGIC PROPERTIES OF THE WATERSHED SOILS

Summary of Soils in Hyrdologic Response Units

HRU	Principal Soils	Slope Range %	Rock Type	General Soil Characteristics
A1, A2	Faraway	35-50	Andesite, rhyolite, basalt	Shallow, rocky medium-textured soils
A3, A4	Barkerville-Gaddes	35-50	Granite, quartzite	Moderately deep gravelly, sandy loam soils
A1, 4A1	Tortugas	30-50	Limestone	Shallow, rocky medium-textured soils
1A2, 4A2	Un-named clay	8-15	Limestone, andesite	Deep clay soil on low benches
1A3, 2A2, 3A3, 4A3, 5B1, 6B1, 7B2, 8B1	Faraway	5-60	Andesite, rhyolite, sandstone	Shallow, rocky medium-textured soils
2A1, 3A1	Showlow, Whitehouse	3-10	Dacite, andesite, diorite, shale, siltstone	Deep, fine-textured alluvial soils
3A1	Showlow, Faraway Whitehouse-Rimrock	0-20	Dacite, andesite, diorite, shale, siltstone	Deep, fine-textured alluvial soils
3A2, 7B4	Rockland		Dacite, andesite, shale, rhyolite	Steep, rocky slopes with pockets of shallow soils
6B2, 8B4	Grebe, Comoro	5-10	Dacite, andesite, shale, limestone, rhyolite	Deep, medium to moderately-coarse textured alluvial soils

HRU	Principal Soils	Slope Range %	Rock Type	General Soil Characteristics
7B1	Tortugas, Lampshire, Graham	30-50	Limestone, rhyolite, dacite, andesite	Shallow, rocky, medium-textured soils
7B2	Faraway, un-named clay	5-60	Andesite, rhyolite, basalt	Shallow, rocky, medium textured and deep clayey soils
7B3, 8B3	Graham	5-20	Andesite, breccia, tuff, basalt	Shallow, stony, fine-textured soils
8B2	Lampshire, Graham	10-60	Andesite, basalt, tuff	Shallow, fine and medium-textured gravelly soil

APPENDIX VIII

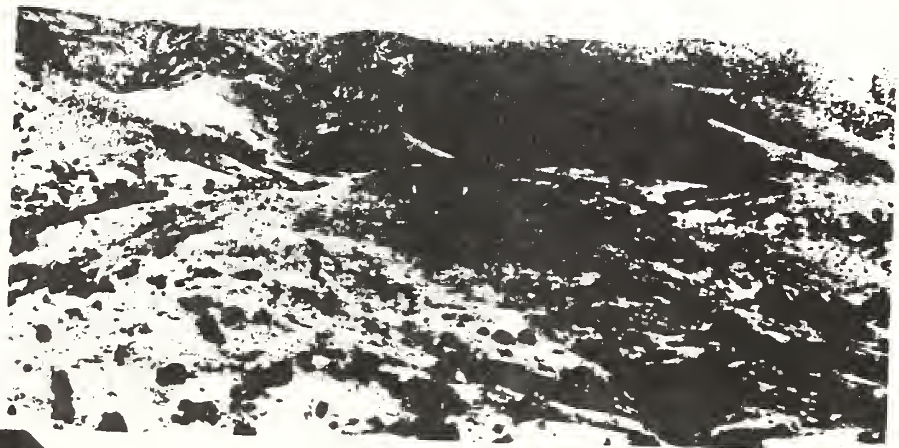
Economic Characteristics of the Red Rock Watershed Area and Methods Used To Derive Coefficients for Economic Evaluation of Proposed Alternatives

Appendix VIII

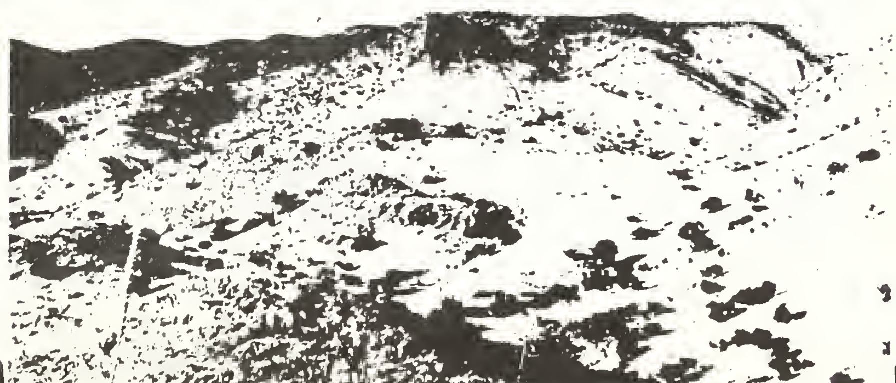
Maps & Photos

I. Table of Contents

1. Map of Red Rock Canyon & Patagonia area
2. Photos of Area
    a. Dam site "A"
    b. U.S.G.S. gage at Circle Z Ranch
    c.



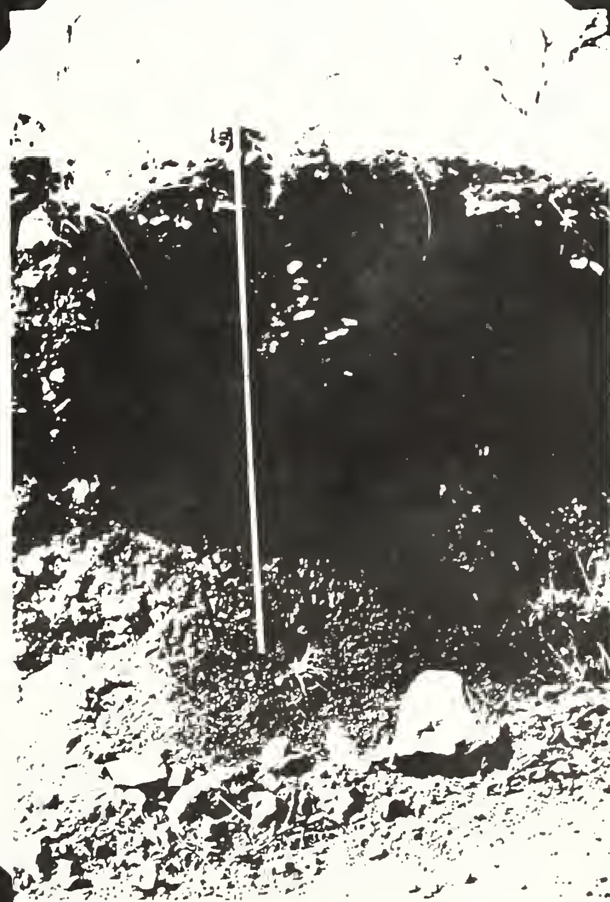
Two views of the Canelo Hills



Ashburn Mountain - West Facing Slope

Mesquite Flat Southwest of Copper Mountain

Makeup of terrace alluvium at Red
Bank Well - Redrock Canyon



Exposures of soil mantle overlying
weathered Andesite

Alluvial Unit #5
Overlaying alluvial
Unit #1 - Redrock
Canyon east of
Seibold Ranch.

Fractured Andesite

Weathered and fractured Andesite

Beginning of surface flow

Surface flow one quarter mile downstream from top picture

Overlying Rhyolite

Overlying Andesite

Closeup view of soil mantle over-
lying weathered Andesite

Red Bank - Outcroping of Rhyolite

Redrock Canyon at Red Bank Well - Site of a seismic determination of alluvial thickness.

Kunde Mountain - East Facing Slope

Kunde Mountain - North Facing Slope

U. S. Geological Survey Gaging Station
Sonoita Creek

Looking East from vicinity of Dam Site "A"

Looking North from Section 16 of T.22S., R.17E.